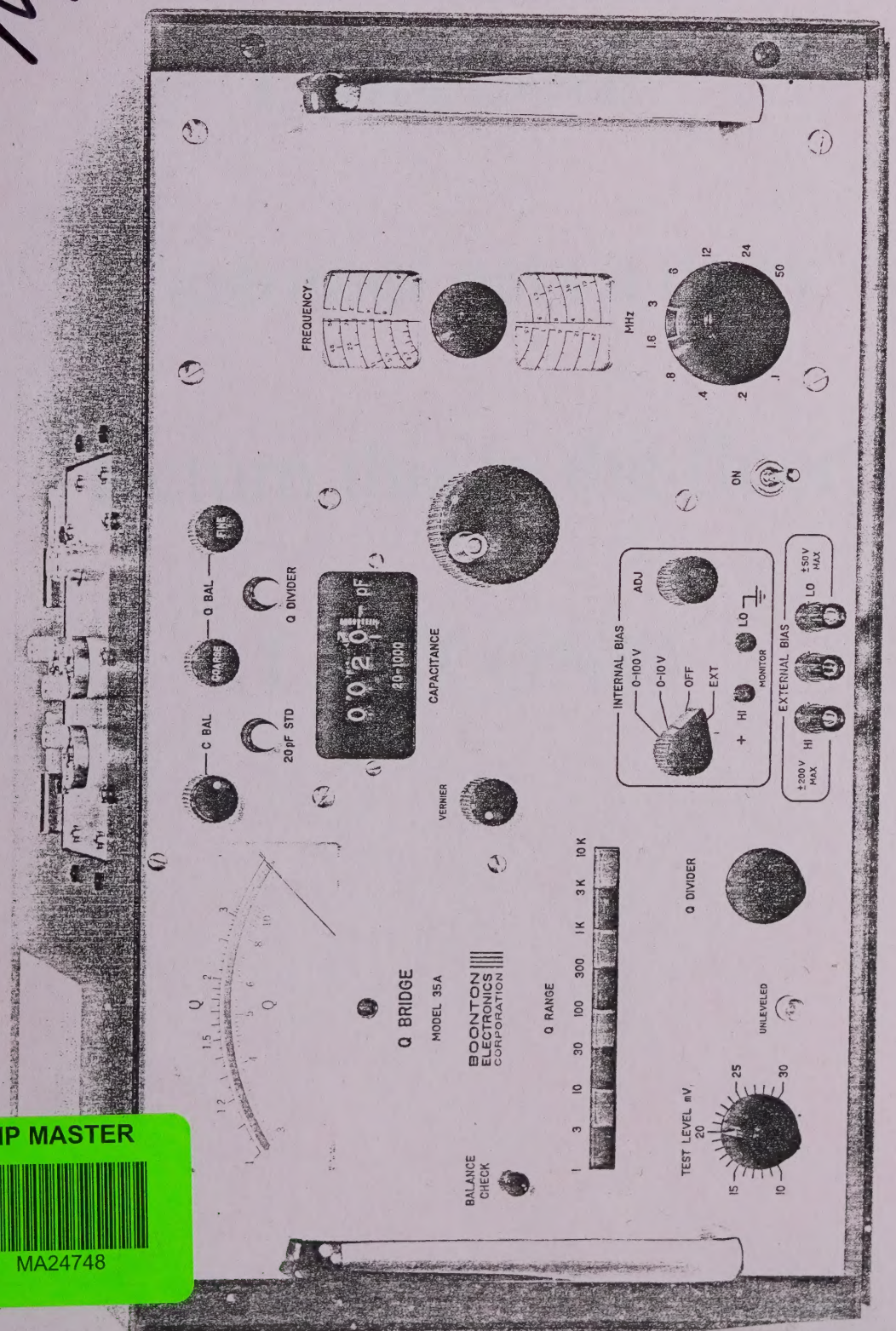
INSTRUCTION MANUAL

MODEL 35A Q-BRIDGE

Serial #135

M E.T. SHOP



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MODEL 35A Q BRIDGE

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CHAPTER 1

EQUIPMENT DESCRIPTION

1.1 INTRODUCTION

The Boonton Model 35A Q Bridge represents a new principle in the measurement of Q and capacitance. With no need for external work coils, resonant circuits or calculations, it provides a direct readout of Q and capacitance at any frequency between 100 kHz and 50 MHz. Values of Q between 5 and 10,000 are read directly from the calibrated panel meter; capacitance from 20 pF to 1000 pF is indicated on the counter-type dial. By the use of an indirect method of measurement, the capacitance range may be extended down to 0.002 pF; capacitors up to 0.25 μF can be measured by a two-terminal indirect method.

In addition to the measurement of capacitors, the Model 35A also measures semiconductor devices under normal bias conditions, the inductance, Q and parallel capacitance of inductors, the series inductance of capacitors, the rf resistance of resistors, the transmission characteristics of filters, and many other component parameters. Thanks to the wide and continuous frequency coverage of the Model 35A, the frequency behavior of the devices measured can easily be determined.

A maximum degree of flexibility has been designed into the Model 35A. All four corners of the bridge are brought out to the terminals on the top terminal plate so all bridge arms can be easily modified by the attachment of accessory capacitors. An internal bias supply is provided, and provision in made for the application of external bias voltages as well.

The directly calibrated test signal generator, continuously adjustable in 9 ranges from 100 kHz to 50 MHz, is ganged to the tuned detector for single-dial tuning. The signal level is adjustable from 10 millivolts to 30 millivolts with a directly-calibrated control; the level is automatically controlled within very close limits.

1.2 SPECIFICATIONS

1.2.1 Capacitance Measurement, Direct

Capacitance Range:	20 - 1000 pF
Frequency Range:	100 kHz - 50 MHz
C Accuracy:	$\pm(0.5 \pm f/50)\% \pm 0.3$ pF
Q Range:	5 - 10,000
Q Accuracy:	$\left[5 + Qf^{0.3}\right]\%$

where: f = frequency in MHz
Q = measured Q

(See Figure 2 for a graphical presentation of this equation.)

NOTE: At frequencies between 20 and 30 MHz, test levels greater than 20 mV may cause measurements of high Q (greater than, say, 1000) to be low and outside specified tolerance. This is the result of harmonic distortion of the test signal and imbalance of the bridge at the second harmonic.

1.2.2 Capacitance Measurement, Indirect

Cap. Range	C Accuracy	Q Range	Q Accuracy
0.002 - 2 pF	±10%	-	-
2 - 20 pF	$\pm(2 + 20/C_x)\%$	0.5 - 5000	$\pm 10\% \pm (2Q/10^3)\%$
1000 pF - 0.25 μF	±5%	-	-

1.2.3 Inductance Measurement

Inductance Range:	0.1 μH - 100 mH
L Accuracy:	±5% (2% using frequency counter)
Q Range:	5 - 500
Q Accuracy:	$\pm 10\% \pm (Q/100)\%$

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1.2.4 Resistance

Resistance Range:	5 ohms - 500 megohms
R Accuracy:	$\pm 10\% + (Q/10^3)\%$

1.2.5 Frequency Range

Frequency:	100 kHz - 50 MHz
Accuracy:	±2%

1.2.6 Test Level Range

10 - 30 millivolts	(See note below)

1.2.7 Bias

Internal:	0 - 100 volts
External:	0 - 200 volts

1.2.8 Power Requirements

115/230 volts, 50/60 Hz

75 watts

1.2.9 Physical Characteristics

Weight	43 pounds
Size:	11 1/2" h x 19 1/2" w x 12 3/4" d

Note: Test level can be measured with an RF Millivoltmeter (such as the Boonton Model 92 Series) connected between the LO test post and GND. The Pulse switch on the rear panel must be turned off when making this measurement, and the Q BAL (Coarse) control fully ccw. 10 - 20 mV is available at all frequencies. 30 mV is available at most frequencies.

1.2.10 Available Accessories

Model 35-4A X10 Range Multiplier. This consists of:

Model 35-1A Fixed Ratio Capacitor

Model 35-2A Variable Ratio Capacitor

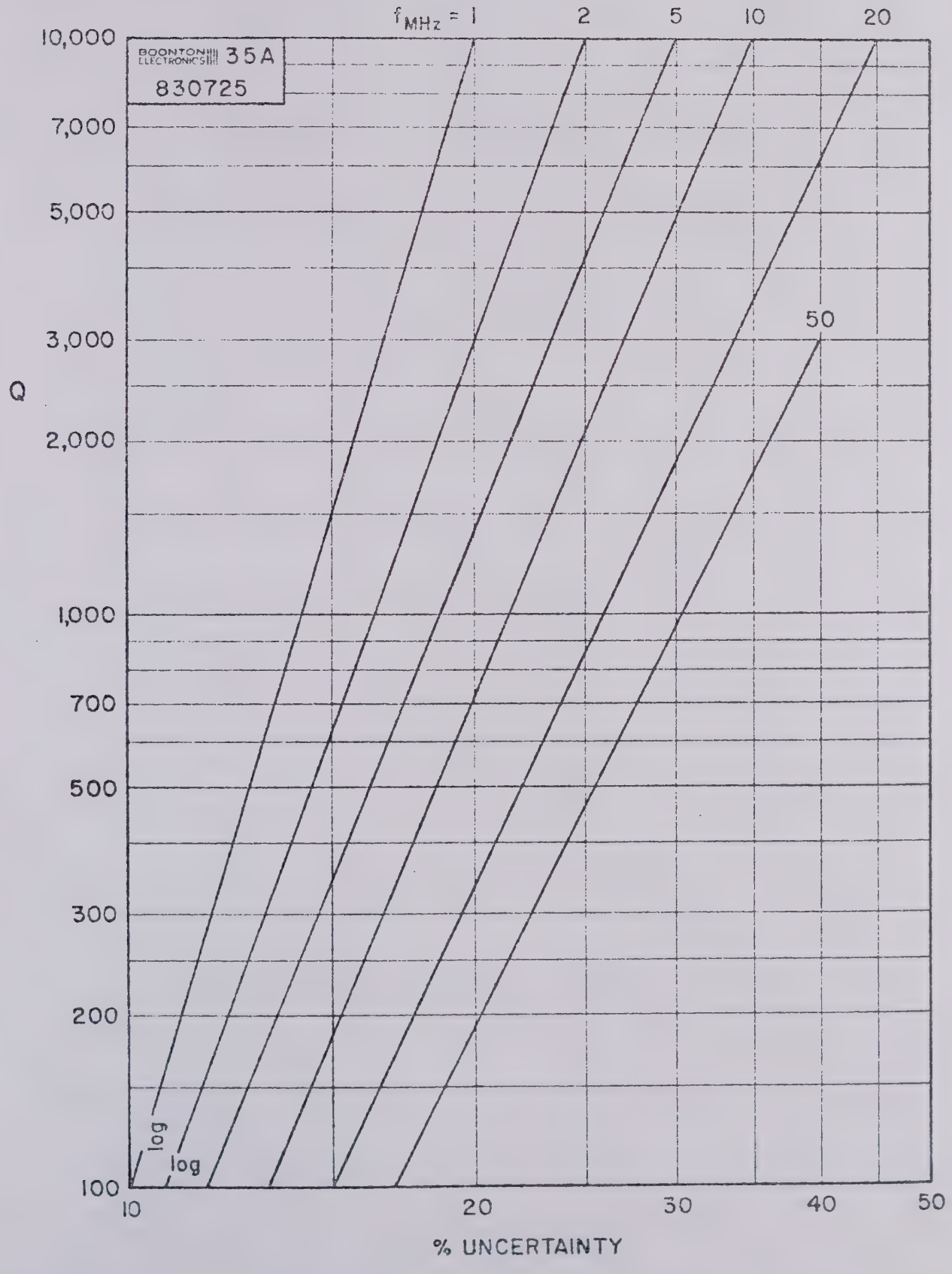
Model 35-3A 200 pF Fixed Capacitor

The Range Multiplier is used in measuring capacitors between 1000 and 10,000 pF, up to 1 MHz.

Model 35-5A 20 pF Work Capacitor. Used in the measurement of capacitors smaller than 20 pF, from 10 to 50 MHz.

Model 35-6A 20 pF Work Capacitor. Used in the measurement of capacitors smaller than 20 pF, from 0.1 to 10 MHz.

Model 35-8A/ - Q Standards.


BOONTON ELECTRONICS 35A
830725
f_{MHz} = 1
2
5
10
20
50
Q
10,000
7,000
5,000
3,000
2,000
1,000
700
500
300
200
100
log
log
10
20
30
40
50
% UNCERTAINTY

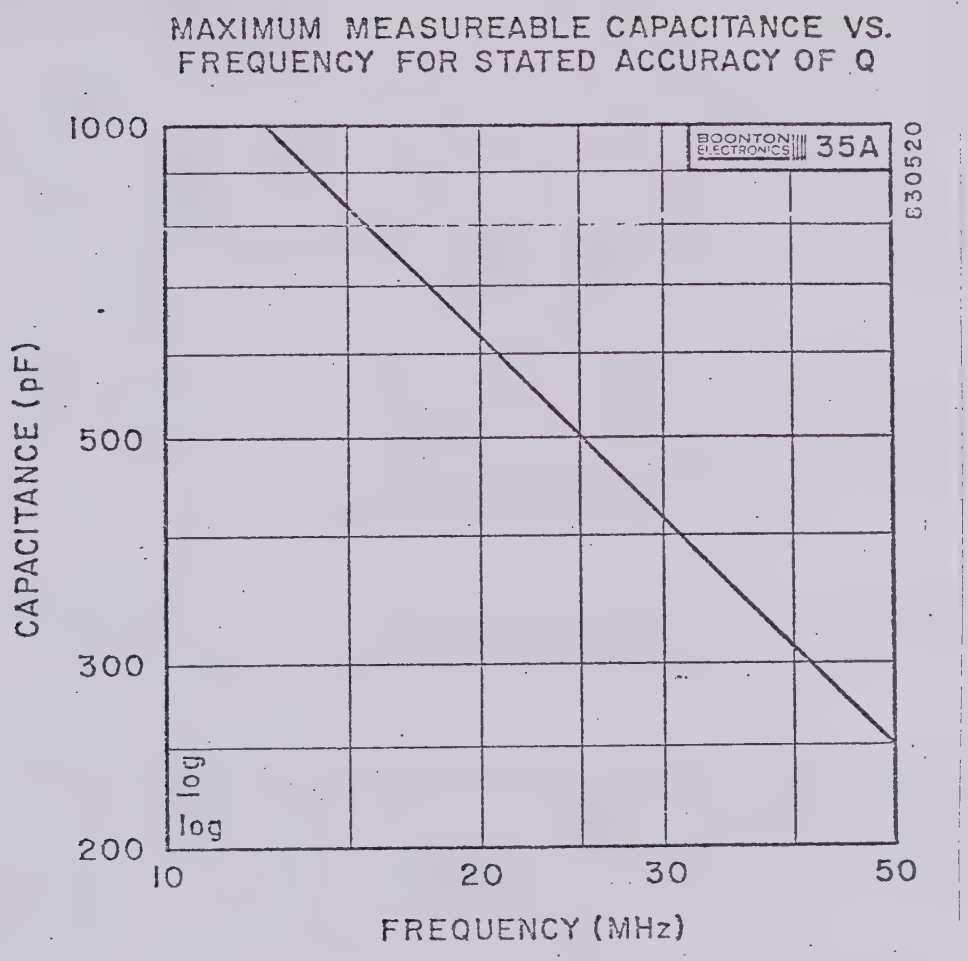


Figure 3. Maximum Capacitance vs Frequency

1.3 Controls and Indicators

ITEM	FUNCTION
CAPACITANCE	The large crank knob is geared to the precision capacitor forming the variable arm of the bridge. The gearing also drives the counter-type indicator, calibrated from 17 pF to 1010 pF, with 0.2 pF resolution.
VERNIER	This controls a 10-turn potentiometer which adjusts the bias on a voltage-variable capacitor across a ratio arm of the bridge. On the highest Q range this control is useful in attaining the sharpest peak on capacitance balance. On the lower Q ranges it has very little effect.
FREQUENCY	This controls the ganged oscillator and detector tuning capacitors. Calibrated in Megahertz, only the tuning range in use is illuminated.
MHz Switch	Bandswitch control for the oscillator and detector sections. This control is arranged in 9 bands, covering the range of 100 kHz to 50 MHz. It selects the appropriate coils in the oscillator and the tuned detector, as well as turning on the correct dial lamp for the range selected.
C BAL	This controls a micrometer-type three-terminal variable vernier capacitor across the main precision variable capacitor.
Q BAL (Coarse)	This rotary tap switch controls the dc bias on a chain of voltage-sensitive diodes connected from the low side of the bridge to ground. Their function is to compensate for the small differences in losses between the two fixed capacitors in the ratio arms of the bridge. In effect, they form a variable resistance of extremely fine resolution.

Q BAL (Fine)	This ten-turn potentiometer furnishes a vernier adjustment of the Coarse switch positions.
20 pF STD	When this button switch is depressed, the internal standard capacitor is connected across the HI and LO bridge terminals. This standard is a special air capacitor of high accuracy and practically infinite Q.
Q DIVIDER (Button)	When this button switch is depressed, it unbalances the bridge network for setting the Q reference point.
Q DIVIDER (Knob)	When the Q DIVIDER switch is in, this control adjusts the gain of the detector to set the Q reference point on the meter indicator.
Q RANGE	This 8-position pushbutton switch sets the gain of the detector section in accurately calibrated steps. To avoid any confusion in reading the meter, the switch buttons are color-keyed to the meter scales.
BALANCE CHECK	This control is used in the final steps of bridge adjustment, after the Q level has been set to 1 and the sharpest point of balance is being sought on the highest Q RANGE position. Pushing the switch button shorts the Q DIVIDER potentiometer and runs the detector system up to full gain, increasing the sensitivity of the meter system and making it easier to peak the reading accurately.
TEST LEVEL	This control adjusts the output level of the signal generator. It is calibrated directly in millivolts.
UNLEVELED lamp	The level of the signal generator output is closely controlled over most of its range. The lamp will light when control is lost; when this occurs, the test level should be backed off a bit until the lamp goes out.

INTERNAL BIAS:

Switch:	The four-position rotary switch selects the following bias conditions: 1. 0 - 100 volts 2. 0 - 10 volts 3. Off 4. EXT This position turns off the internal bias supply and connects the bridge bias circuits to the EXTERNAL BIAS binding posts.
ADJ	A ten-turn potentiometer used to set the internal bias voltage to the desired value. This is inoperable when the Bias Switch is in the EXT position.
Monitor	Tip jacks used to connect a dc voltmeter for monitoring the internal bias voltage level. They are not active in the EXT position.
EXTERNAL BIAS	Binding posts providing for external bias connection; two different voltages or different polarities can be used in a three-terminal mode if desired. The voltage limitations printed on the panel should be observed.

1.4 Oscillator Frequency Check

When the nature of the measurements to be made with the Model 35A require that the frequency be known to a higher degree of accuracy than the specified 2% figure, the frequency may be measured with the aid of a frequency counter. To do this, attach the counter to the Type N coaxial jack on the top terminal plate of the 35A. Turn the "Pulse" switch on the rear apron off, and then adjust the FREQUENCY control slowly until the counter registers the proper frequency. Remove the counter cable and turn the Pulse switch on.

CHAPTER II

INSTALLATION

2.1 UNPACKING AND INSPECTION

2.1.1 Unpacking

The instrument is supported in the carton by the notches in the four corner cylinders of plastic foam material. After opening the top of the carton, take hold of the two front panel handles through their plastic covering and slowly pull the instrument up out of the carton. Remove the plastic covering from the cabinet and strip off the plastic sleeves from the handles. Check the carton thoroughly for any shipping documents. It is strongly recommended that the carton and the packing materials be carefully saved for possible reshipment in the future, as the packing has been very carefully designed to protect the instrument in transit.

2.1.2 Inspection

Once the instrument is out of the carton, it should be inspected for any signs of physical damage resulting from shipment. If any damage is found, be sure to notify the carrier and the factory immediately.

2.2 INSTALLATION

Make certain that the voltage change switch on the rear panel is set to the local power-line voltage (117 volts or 230 volts) and plug the cable into a power receptacle.

2.3 PACKING FOR RESHIPMENT

If it should become necessary, for any reason, to return the instrument to the factory, the company must be so notified before shipping. Please follow these special packing instructions:

a. If possible, use the original packing material and carton.

b. Tie the ac power cable firmly to the cabinet.

c. Tie a tag or envelope to a front-panel handle with the following data:

1. Name and address of purchaser.

2. Model and serial number.

3. Full description of damage or defect.

CHAPTER III

OPERATION

3.1 Preliminary Adjustments

It is recommended that the description of the controls and indicators in Par. 1.3 be studied to gain some degree of familiarity with their functions.

Be sure that the voltage change switch on the rear panel is set to the proper position for the local line voltage (117 or 230 volts), and plug the power line connector into a power receptacle. Turn the power switch on and allow the instrument to warm up for an hour before going on to the next step.

3.1.1 Initial Control Settings.

INITIAL CONTROL SETTINGS

1.	FREQUENCY	As required
2.	TEST LEVEL	20 mV
3.	Q RANGE	1 - 3
4.	Q DIVIDER (Knob)	Fully ccw
5.	VERNIER	Midrange
6.	20 pF STD	In (lighted)
7.	C BAL	Midrange
8.	Q BAL (Coarse)	ccw at 100 kHz, cw at 50 MHz
9.	Q BAL (Fine)	Midrange
10.	CAPACITANCE	20 pF

3.1.2 Initial Bridge Balance:

Note: There should be nothing connected to the terminals, and the terminal shield cover should be closed. Controls should be set as shown in 3.1.1.

1. Adjust the C BAL and the D BAL controls alternately for the highest possible meter indication. (Notice that this is the reverse of the usual bridge-balancing procedure in which the controls are adjusted for a minimum meter reading.)

2. Go to the next highest range on the Q RANGE switch and repeat the adjustment of the C BAL and Q BAL controls for a maximum meter indication.

3. Repeat this process for successive positions of the Q RANGE switch until the 3k - 10k position is reached. Press in and hold the BALANCE CHECK button with one hand while using the VERNIER and the Q BAL (Fine) controls to complete the balancing process. When this final adjustment is correctly made the meter pointer should approach the right-hand end of the scale (∞).

4. Return to the lowest position of the Q RANGE switch (1 - 3) and release the 20 pF STD button. The Model 35A is now balanced and ready for use.

   Note: The bridge must be rebalanced whenever frequency is changed or the test level is altered appreciably.

3.2 MEASUREMENT OF CAPACITANCE AND Q

3.2.1 Capacitors between 20 and 1000 pF (direct measurement)

a. Balance the bridge at the desired test frequency (3.1.2).

b. Connect the unknown capacitor between the HI and LO terminals on the top terminal plate and close the terminal shield cover.

c. Adjust the CAPACITANCE control for a maximum meter indication.

d. Switch to the next highest range on the Q RANGE switch and repeat the CAPACITANCE adjustment. Continue this process up through all the positions of the Q RANGE switch until the maximum possible meter reading is achieved.

e. Return to the 1 - 3 position of the Q RANGE switch, push in the Q DIVIDER button, and adjust the Q DIVIDER control for a Q setting of 1 on the meter. Release the Q DIVIDER button.

   At certain frequencies, and with small values of capacitance, it may be difficult to reach a Q setting of 1. This may be rectified by increasing the Test Level.* If a low test level is essential, an alternative procedure is to set the Q Divider for a Q setting of 2, then divide the final Q reading by this factor.

* See note on Page 2.

f. Return to the highest usable position of the Q RANGE switch and repeak the CAPACITANCE control, using the VERNIER control on the highest range. For the final adjustment, hold in the BALANCE CHECK button while adjusting the VERNIER control.

g. Read the Q on the meter, in conjunction with the Q RANGE switch position.

h. Read the capacitance on the counter dial.

3.2.1.1 Very High Q

It will occasionally be found that a capacitor has a Q higher than the limit of the Q-Bridge (10,000). In many cases, particularly with specimens of fairly high capacitance, it is possible to measure Q's above 10,000 by using the technique described in the following paragraph.

1. Follow the standard procedure for balancing and measuring the test specimen on the Q-Bridge up to the highest position of the RANGE switch (3K - 10K).

2. Switch to the 1K - 3K range and adjust the VERNIER capacitance control for a convenient reading on the meter - 3000, for example.

3. Adjust the Q DIVIDER control for a meter reading of, say, 1000, giving a Q multiplying factor of 3.0.

4. Readjust the VERNIER capacitance control for a peak reading on the meter, switching to the highest position of the RANGE switch, if necessary.

5. Read the meter, applying a multiplying factor (in this instance) 3.0.

NOTE: In each case, the multiplying factor is obtained by dividing the reading in Step 2 by that in Step 3. In the example given, this factor is 3000/1000 = 3.0. This procedure actually sets the Q divide factor to a value of less than 1.0, which cannot be read on the meter. In the example given, this factor would be 0.333. Because it is easier to multiply by 3, we recommend using the reciprocal for multiplication of the Q reading.

3.2.2 Capacitors between 2 and 20 pF (Indirect measurement)

(1) Frequencies between 100 kHz and 20 MHz:

a. Balance the bridge at the desired test frequency (3.2.1). Do not release the 20 pF STD button after balancing.

b. Connect the unknown capacitor between the HI and LO terminals.

c. Adjust the CAPACITANCE control for a maximum meter indication, working up through the Q RANGE switch positions as described in 3.2.1 above.

d. Return to the 1 - 3 position of the Q RANGE switch and adjust the Q DIVIDER control for a reading of 1 on the meter. If it is not possible to reach 1, set the control for a convenient value, such as 2, 5, or 10. (Q_r)

e. Return to the highest usable position of the Q RANGE switch and repeak the controls as in 3.2.1. When the highest possible meter reading is reached, record the value. Compute C_X and Q_X using the equations:

$$C_X = C - 20\ pF$$

$$Q_X = Q[C_X/(C_X + 20)]$$

f. If a reference for Q_r other than 1 has been used, then:

$$Q_X = (Q/Q_r)[C_X/(C_X + 20)]$$

(2) Frequencies between 20 MHz and 50 MHz:

The measurement of capacitors of less than 20 pF requires the use of an additional capacitor (usually referred to as a work capacitor) at the test terminals to bring the total terminal capacitance to 20 pF or more. At frequencies of 20 MHz and below, the internal 20 pF standard may be left in the test circuit to serve as a work capacitor ($Q_W = \infty$). This is the method detailed in Section 3.2.2. At frequencies above 20 MHz the internal 20 pF standard is used to make the initial bridge balance but, because the connection of a test capacitor cannot be made directly at the true internal terminals of this standard capacitor, an external capacitor must be used on the test terminals as a work capacitor. In this case, the Q of the work capacitor will be finite, and should be measureable on the Q Bridge.

There are times when it may be advantageous to use an external work capacitor of finite Q at frequencies of 20 MHz or less, rather than the internal standard capacitor of infinite Q. This is evident by rearranging the equation of Paragraph 3.2.2 (1) e. to solve for the measured Q in terms of Q_X and C_X:

$$Q = Q_X(1 + 20/C_X)$$

It is clear that, for small values of test capacitance, the measured Q will be substantially greater than Q_X. For example, if the test capacitance is 2 pF, the measured Q of the combination of internal 20 pF and the external test capacitance will be 11 times the Q of the test specimen. With the normal measuring limit for Q of 10,000, the Q of the test specimen cannot exceed 910. If, however, an external work capacitor with a Q_W of 10,000 is used in conjunction with a test capacitor, values of Q_X up to 10,000 may be measured.

This extension is not gained without some sacrifice. In this case, the rate of change (slope) of measured Q as a function of Q_X is higher than desirable, especially for low values of test capacitance. The uncertainty of the measurement is increased, but careful measuring techniques will often provide suitable results that cannot be obtained by other means.

Method

a. Balance the bridge at the desired test frequency, following the method in 3.1.2. After balance, release the 20 pF STD button.

b. Connect a high Q capacitor of about 20 pF (a ceramic monolithic type is suitable) to the rear binding posts on the HI and LO test terminals. This capacitor is called the "work capacitor."

c. Measure the capacitance and Q of the work capacitor (3.2.1) and record the values obtained.

d. Attach the test capacitor to the front binding posts on the HI and LO test terminals, leaving the work capacitor connected.

e. Measure the capacitance and Q of the paralleled work and test capacitors and record the values obtained.

f. Compute the capacitance and Q of the test capacitor as follows:

$$C_x = C - C_w$$

$$Q_x = \frac{Q}{1 + \frac{C_w}{C_x} - \frac{QC_w}{Q_w C_x}}$$

NOTE: This measurement can most easily be accomplished with the use of the accessory Model 35-5A Work Capacitor, which has an adjustable Q. By setting the Q to one of three values, the value of Q_x can be read directly on the curves supplied with the accessory, thus avoiding computation. See Paragraph 3.3.5 for detailed explanation of this accessory and its use.

3.2.3 Capacitors between 0.002 and 2 pF (Q greater than 5)

Note: Measurement of Q in this capacitance range is not feasible.

a. Balance the bridge at the desired test frequency (3.1.2). Do not release the 20 pF STD button after balancing.

b. Push the Q DIVIDER button in and adjust the Q DIVIDER control for a meter reading of 1. Release the button.

c. Connect the unknown capacitor between the HI and LO posts.

d. Without adjusting the bridge, read the meter and record the reading. Compute C using the equation:

$$C_x = 20/Q \quad (Q = \text{meter reading})$$

3.2.4 Capacitors between 0.001 and 0.25 μF

This is a two-terminal measurement, limited to frequencies between 100 kHz and 5 MHz.*

a. Provide a work capacitor with a capacitance between 100 and 1000 pF. This is designated C_w.

b. Connect the work capacitor between the HI and LO posts and measure its C, using the standard method (3.2.1). Record the resultant capacitance.

c. Connect the unknown capacitor (C_w) between the LO post and ground, leaving C_w connected between the HI and LO posts.

d. Adjust the CAPACITANCE control for the highest possible meter indication, going up through the Q RANGE switch positions in the standard method. Record the resultant CAPACITANCE dial reading (C).

e. Compute the capacitance of the unknown capacitor, using the equation:

$$C_x = C_r(C_w/C - 1)$$

where C_r = the larger bridge ratio capacitor. (Approximately 5400 pF)

(See Section 3.2.4.1 below for the value of C_r)

3.2.4.1 To measure C_r:

a. Provide two capacitors of moderate to high Q, with a capacitance of about 900 pF. Measure each of these on the bridge, following the standard method (Par. 3.1.2). Record the C values obtained.

b. Connect one of these capacitors between the HI and LO posts and the other between the LO post and GND. Adjust the CAPACITANCE control for the maximum possible meter reading and record the capacitance value obtained.

*By using the accessory Model 35-4A Capacitance Range Multiplier, three-terminal measurements can be made from 1000 to 10,000 pF up to 1 MHz. See Paragraph 3.3.7 for an explanation of this accessory and its method of use.

c. Compute the value of the bridge ratio capacitor (C_r) using the equation:

$$C_r = C_2/(C_1/C - 1)$$

where C_1 = capacitance across HI and LO posts

C_2 = capacitance from LO post to GND

C = capacitance dial reading

d. Record this resultant value of C_r.

3.3 OTHER MEASUREMENTS

3.3.1 Inductance and Q of Inductors

This method measures the capacitance required to resonate the inductor at the test frequency. The inductance and Q may then be obtained by simple calculation from the values obtained. At present, the measurement of Q is limited to inductors having Q's less than 200.

A work capacitor with a Q of 300 or more is required. The approximate capacitance of this work capacitor for different frequencies and values of inductance may be estimated from the chart in Figure 6.

a. Balance the bridge at the desired test frequency (3.2.1).

b. Connect the work capacitor (C_w) between the HI and LO posts.

c. Measure the capacitance and Q of the work capacitor, using the standard method in Par. 3.2.1. Record the value of C_w.

d. If the Q obtained in the above measurement is greater than 300, connect a resistor in parallel with the capacitor to lower the Q of the combination to about 300. Measure and record this value of Q_w.

e. Connect the unknown inductor across the work capacitor. Return to a lower range on the Q RANGE switch and repeat the measurement of capacitance and Q of this combination. Record the resultant Q value and the CAPACITANCE dial reading C.

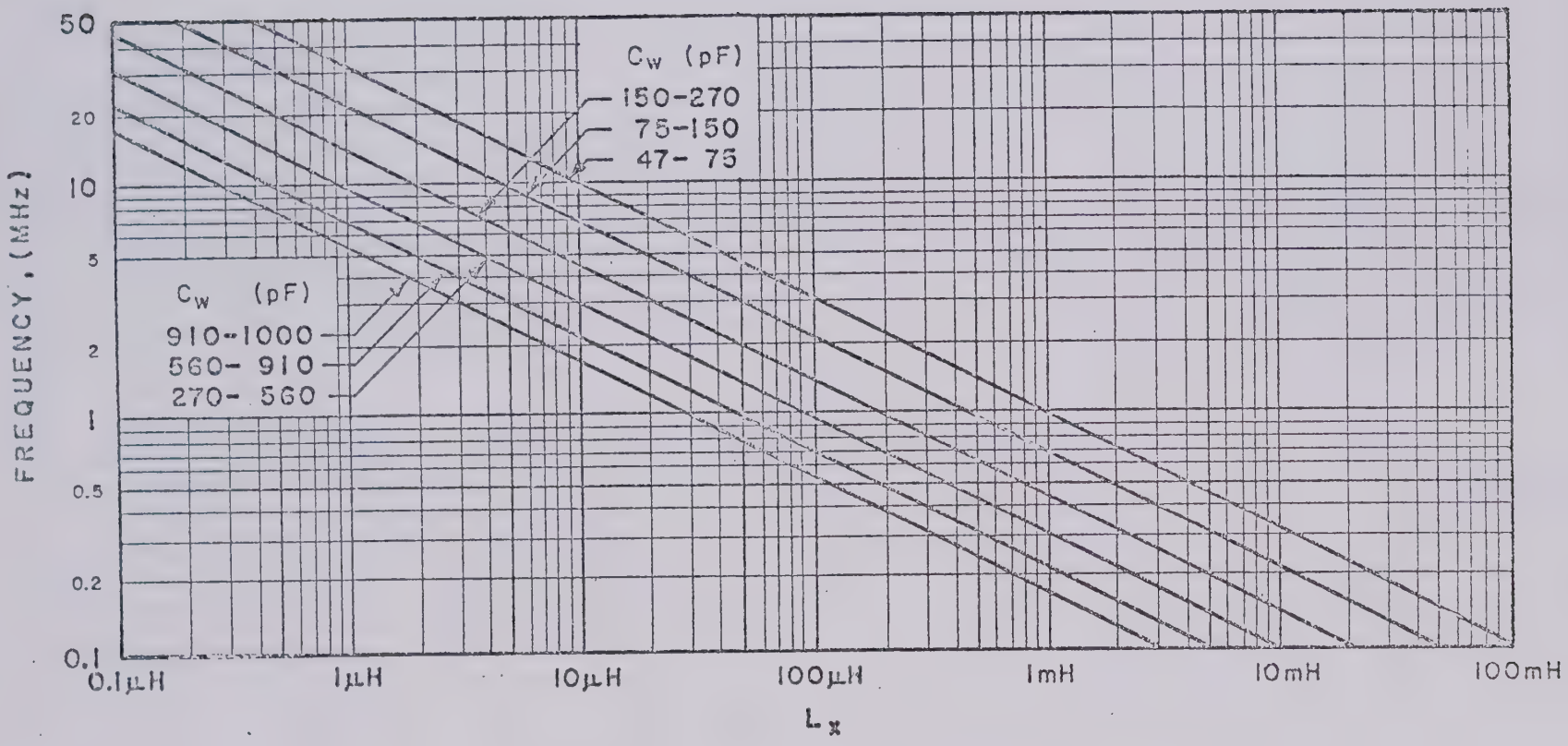


Figure 4. Work Capacitance Selection Chart.

WORK CAPACITANCE SELECTION CHART FOR INDUCTANCE MEASUREMENTS

Example:	Approx. Inductance:	8 μH
	Test Frequency:	7.9 MHz
	Work Capacitance:	75/150 pF

f. Compute the inductance and Q using the equations:

1. $L_x = 1/\omega^2 \Delta C$

   where $\omega = 2\pi f$

   $\Delta C = C_w - C$

2. $Q_L = \dfrac{\Delta C}{\dfrac{C}{Q} - \dfrac{C_w}{Q_w}}$ (C may be in any units, i.e., Farads, picofarads, etc.)

3. If $Q \ll 300$, then $Q_L \approx Q(C_w/C - 1)$

3.3.2 Resistance, Three-Terminal (50Ω to 500 MΩ)

a. Balance the bridge at the desired test frequency (3.2.1).

b. Connect the unknown resistance between the HI and LO posts.

c. Adjust the CAPACITANCE control for a maximum indication on the meter.

d. Switch to successively higher positions of the Q RANGE switch, adjusting the CAPACITANCE control for meter maximum in each range.

e. When the maximum possible meter reading is obtained, return to the 1 - 3 position of the Q RANGE switch, hold in the Q DIVIDER button, and adjust the Q DIVIDER control for a meter reading of 1. Release the Q DIVIDER button and return to the previous position of the Q RANGE switch.

f. Recheck the CAPACITANCE control for a maximum Q reading, then record the Q and C readings.

Then,

$$R_x = Q/\omega C$$

where $\omega = 2\pi f$

C = the CAPACITANCE dial reading

If the change of the capacitance dial is less than 1 pF from the original balance setting of 20 pF, then

$$R_x = 8Q/f \quad (k\Omega)$$

where f is in MHz

g. If the indicated Q with the resistor connected to the terminals is less than 5 (lowest measureable Q), at the required measuring frequency, a work capacitor should be added across the test terminals to allow Q to fall within the measureable range. If the resistance to be measured is known approximately, the work capacitor should be equal to, or greater than, 800/fR picofarads, where f is in MHz and R is in kΩ.

Because the addition of a work capacitor is only recommended for those cases where the Q reading falls below the minimum measureable value of 5, the Q of the work capacitor need not be exceptionally high. A mica capacitor will normally have a good enough Q to support this measurement.

3.3.3 Resistance, Two-Terminal (5Ω to 1.5 MΩ)

a. Balance the bridge at the desired test frequency (3.2.1).

b. Connect the unknown resistance between the LO post and ground.

c. Adjust the CAPACITANCE control for a maximum indication on the meter, working up through progressively higher positions of the Q RANGE switch until the highest possible reading is obtained.

d. Return to the 1 - 3 position of the Q RANGE switch, hold in the Q DIVIDER button, and adjust the Q DIVIDER control for a reading of 1 on the meter. Return to the previous position of the Q RANGE switch.

e. Recheck the peak setting of the CAPACITANCE control and record the Q reading.

f. Compute the resistance using the equation:

$$R_x = Q/\omega C_r$$

where C_r = the value of the larger of the two bridge ratio capacitors.

The value of C_r is not controlled and must be experimentally determined for each instrument. A method of measuring C_r is given in Section 3.2.4.1.

Instead of measuring C_r, a reasonable approximation of the resistance may be made using the equation:

$$R_x \approx 30Q/f$$

where f is in MHz and R is in ohms.

3.3.4 Self-Resonant Frequency of Inductors

A. Three-terminal measurement:

1. Set the FREQUENCY control and band switch to the approximate frequency at which resonance is estimated. Set the CAPACITANCE control to 20 pF, and the 20 pF STD button switch in (lighted). Set the Q BAL control fully ccw and balance the bridge, using the C BAL control, for a Q reading of 300 or greater.

2. Connect the unknown inductor between the HI and LO posts. Set the Q RANGE switch to the 1 - 3 position and adjust the Q DIVIDER control for a mid-scale meter reading, adjusting the TEST LEVEL control if necessary.

3. Vary the FREQUENCY control through its range, turning it in the direction which gives an increasing meter reading. Switch to successively higher positions of the Q RANGE switch as needed to keep the meter reading on-scale. At some point in the frequency sweep, a fairly sharp peak will be observed as the frequency passes through the self-resonant frequency of the inductor. Be sure to keep this peak reading on-scale by using the Q RANGE switch and Q DIVIDER control to prevent any ambiguity in the exact frequency of resonance.

Note: This three-terminal method excludes the effect of terminal and lead capacitance to ground; the self-resonant frequency obtained will thus be somewhat higher than when measured in a grounded mode. If the ultimate use of the inductor will be in a circuit with one end grounded, the following method will give a result closer to that obtained in actual use.

B. Two-Terminal Measurement:

1. A flat metal plate, large enough to extend an inch or more beyond the periphery of the inductor, should be connected firmly to the LO post.

2. Balance the bridge as in Par. 1, Section A, above.

3. Connect the unknown inductor between the LO post (or the ground plane) and the HI post. Position it as closely as possible with relation to the ground plane as it will be to ground in the actual installation.

4. Make the measurement in the same manner as in Section A above.

3.3.5 Self-Resonant Frequency of Capacitors

a. Connect the capacitor to be measured between the HI post and GND, using the lead lengths which will be included in the eventual installation of the capacitor. The bridge need not be balanced for this measurement; the CAPACITANCE control should be turned to 200 pF or higher and left there.

b. Set the Q RANGE switch to the 1 - 3 position. Set the FREQUENCY control and switch to the estimated frequency of resonance. If the neighborhood of resonance cannot be estimated, set the frequency at some low value such as 1 MHz.

c. With the TEST LEVEL control at 20 mV, the meter should show a reading in the upper half of the scale. If it exhibits a reading of <1, adjust the Q DIVIDER control to bring it up on the scale. The exact level is not important.

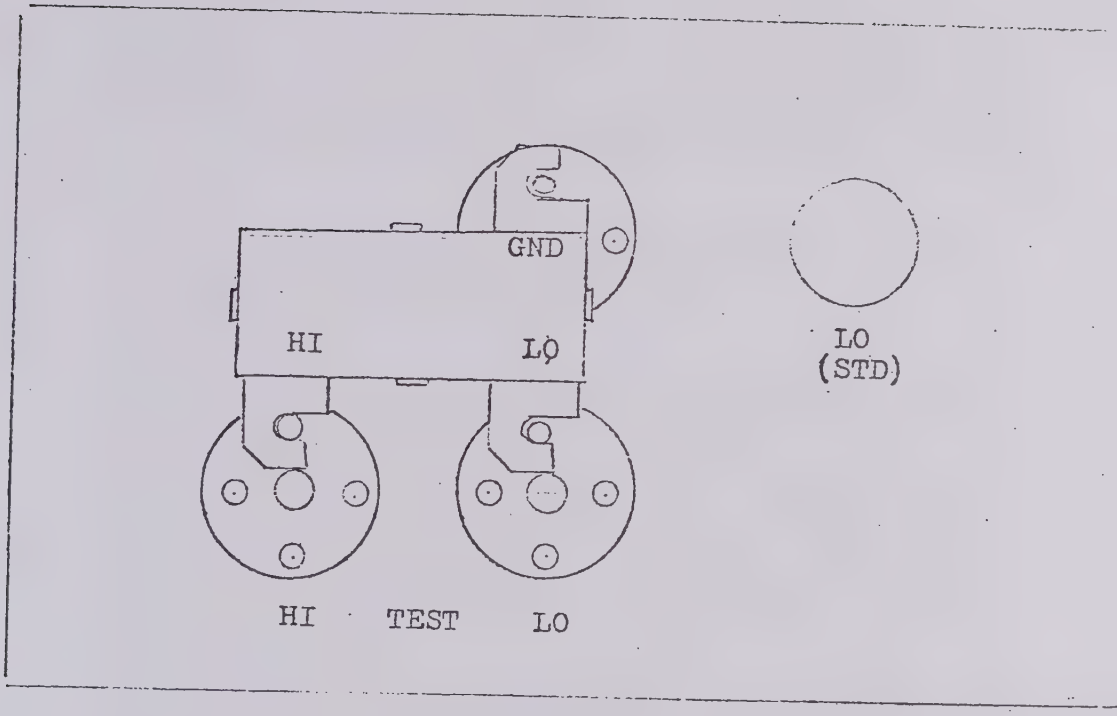
d. Slowly turn the FREQUENCY control through its range, going to successively higher ranges on the Q RANGE switch to keep the meter reading on scale. Continue this until a fairly sharp peak is noted, typical of a resonant condition. The frequency at which this peak occurs is the self-resonant frequency of the capacitor and its leads.

3.3.6 Measurement Procedure for Model 35-5A Work Capacitor

This method may be used when measuring capacitors of less than 20 pF at frequencies between 10 and 50 MHz. Q of the Model 35-5A must be adjusted at the measurement frequency.

a. With nothing connected to the HI and LO test posts of the 35A, balance the instrument at the desired frequency in the normal manner (Para 3.1.2).

b. Connect Model 35-5A Work Capacitor to the bridge so that each tab contacts its appropriate test post at the rearmost screw terminal position. The tabs are marked HI, LO and GND. See drawing on Page 26 for correct placement.



35A Top Plate

c. Use the standard measurement procedure (Para. 3.2.1) to measure the Q and the capacitance of the Work Capacitor.

d. Use the insulated adjusting tool inserted in the appropriate hole on the left hand side of the work capacitor to set its Q to the desired value which will be indicated on the 35A. The capacitance balance should be rechecked after each adjustment. Q values between 2000 and 10,000 may be set (use Q = 2000, 5000, or 10,000 if supplied curves are to be used).

ADJ Q_W (1) should have sufficient range to set most Q values at most frequencies but if coarse adjustment is needed use ADJ Q (2). This adjustment will also affect C_W to a small degree.

NOTE: At some frequencies the range of Q_W obtained with ADJ Q_W (1) may change so that the maximum Q_W will be greater than 10,000. Further adjustment of ADJ Q_W (1) in a clockwise direction, or of ADJ Q_W (2) in a counter-clockwise direction may cause Q_W to go to infinity, and even reverse, giving an 'on scale' reading, but with an effective Q_W that is negative. A negative Q_W is the result of an out-of-phase condition and does not represent a source of energy. It is not recommended that negative values of Q_W be used, but valid measurements can be made provided the proper sign is used in the appropriate equation.

To avoid this condition, a simple test for positive values of Q_W can be made. With the bridge balanced for a finite value of Q_W, momentarily turn the 35A Q BAL FINE knob in a counter-clockwise direction. The value of Q_W will decrease if Q_W is positive.

The range of the ADJ Q_W (1) control may be properly set with the coarse control, ADJ Q (2). During the adjustments of Q_W (1) and (2), the desired condition of a positive Q_W may be determined by noting that Q_W decreases when ADJ Q_W (1) is turned CCW and ADJ Q_W (2) is turned CW.

e. Record Q_W and C_W.

NOTE: It is more convenient when computing C_X if the C_W reading on the 35A is set to 24 pF and the C BAL control is reset to restore bridge balance. (This is optional)

f. Leaving the work capacitor connected, attach the specimen to the HI and LO test posts. Extra screw terminals should be inserted into the front threaded holes in the test posts for this purpose.

g. Again following the standard procedure, measure the Q and capacitance of the combination of the specimen and work capacitor. Record values Q and C

h. Compute the specimen's Q (Q_x) and capacitance (C_x) as follows:

a. $C_x = C - C_w$ or $C_x = C - 24$ pF (see e.)

b. $$Q_x = \frac{Q}{1 + (C_w/C_x) - (C_w/C_x)(Q/Q_w)}$$

If Q_w was set to 2000, 5000 or 10,000 one of the curves supplied may be used to find Q_x.

3.3.7 Model 35-4A X10 Capacitance Range Multiplier

Three-terminal measurements of capacitors between 1000 and 10,000 pF, up to 1 MHz, with direct readings of C and Q are made with the Model 35-4A X10 Capacitance Range Multiplier. This consists of three components: a fixed ratio capacitor (35-1A), a variable ratio capacitor (35-2A), and a 200 pF capacitor (35-3A). The measurement accuracy with the 35-4A is:

C accuracy: $\pm(1 = C/10^4)\% \pm 3$ pF

Q accuracy: $\pm 10\% \pm(2Q/10^3)\%$

Method

a. With the terminals of the 35A empty, balance the instrument in the standard manner (Para. 3.1.2).

b. Connect the 200 pF capacitor between the HI and LO Test posts. Using the standard procedure (Para. 3.2.1), measure the capacitance of this capacitor and record the result.

c. Leaving the 200 pF capacitor in place, connect the fixed ratio capacitor between the LO Test post and the GND post. Mount the variable ratio capacitor to the LO (STD) coaxial connector. Set the CAPACITANCE dial to read one-tenth of the capacitance value previously recorded in Step 2.

d. Set the Q RANGE switch to a low range (10 - 30). Carefully adjust the small knurled knob on the top of the variable ratio capacitor case for a maximum meter indication. Then, working up through the Q RANGE switch positions, adjust the Q BAL and C BAL controls for maximum meter readings until the highest possible peak is reached. Then hold in the BALANCE CHECK button and touch up the balance controls again for the highest reading.

e. Remove the 200 pF capacitor from the HI and LO posts and connect the unknown capacitor in its place. Do not remove the fixed or variable ratio capacitors.

f. Return to a low position of the Q RANGE switch and tune the CAPACITANCE control for a peak meter indication. Work up through the Q RANGE switch positions, peaking the CAPACITANCE control, until the maximum possible meter reading is reached. Return to the 1 - 3 position of the Q RANGE switch, push in the Q DIVIDER button, and adjust the Q DIVIDER control for a reading of 1 on the meter. Release the Q DIVIDER button, return to the previous setting of the Q RANGE switch, and touch up the CAPACITANCEcontrol for a peak.

g. Read the Q of the specimen directly from the meter. Multiply the reading of the CAPACITANCE dial by ten to obtain the capacitance of the specimen.

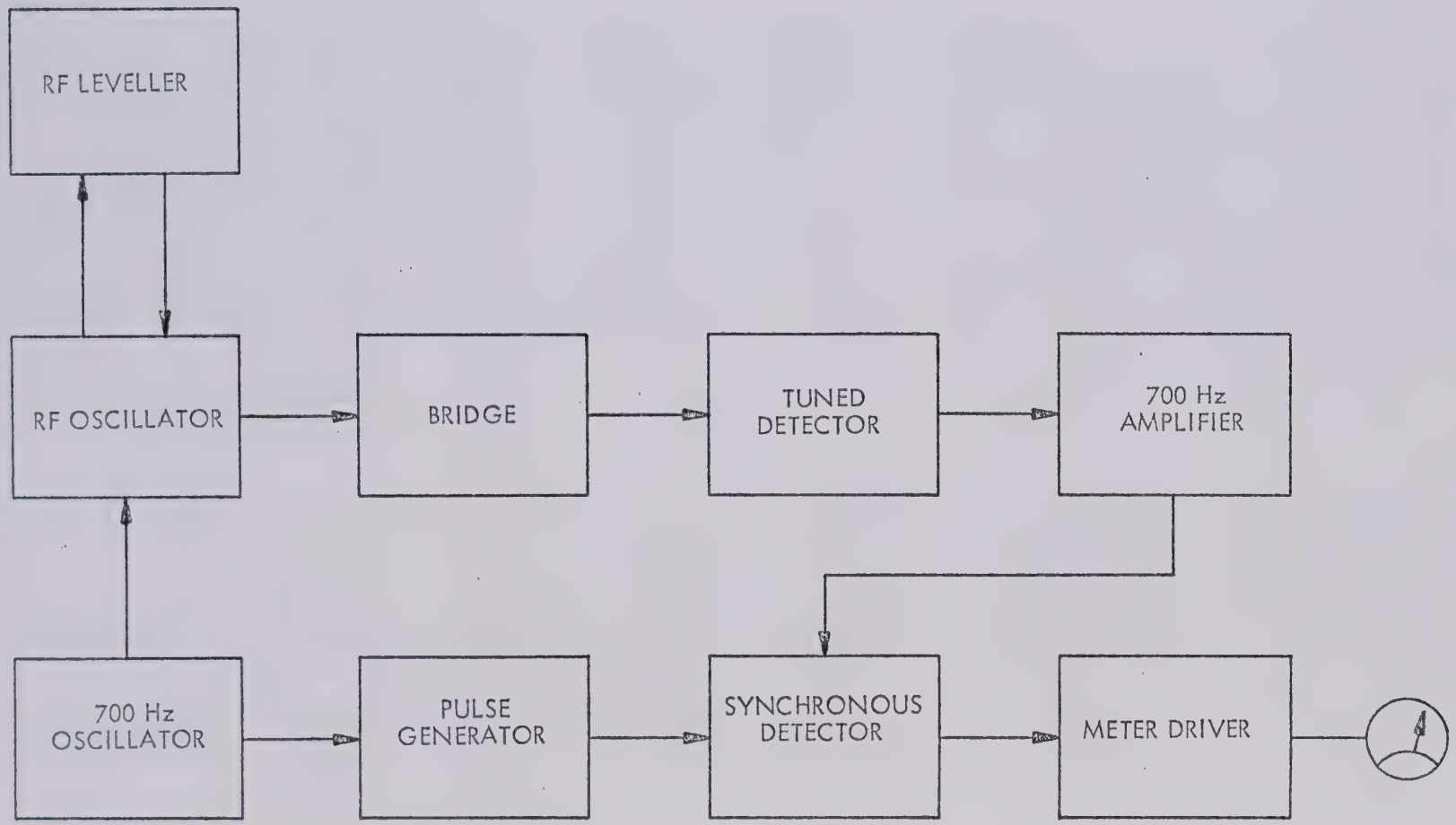


Figure5 - Block Diagram, Model 35A Q Bridge

CHAPTER IV

THEORY OF OPERATION

4.1 Basic Description

The Model 35A Q Bridge measures the Q of a capacitor in a manner quite different from methods usually employed. The capacitance of the test specimen is measured directly with a ratio capacitance bridge, adjusting only the variable standard capacitance for balance. At balance, the amplitude of the residual signal from the bridge is proportional to the dissipation (D) of the test specimen, provided that all losses in the other arms of the bridge are initially balanced. The signal is then processed to provide a reading of Q (1/D).

The explanation that follows, although necessarily somewhat cursory, may serve to make clear the basic workings of the 35A. Figure 7 illustrates in block form the sections of the instrument and the manner in which they are interconnected; Figure 8 shows the basic bridge circuit in simplified form for greater clarity in connection with this explanation.

Referring now to the block diagram (Figure 7), the RF Oscillator is a bandswitched circuit covering the frequency range of 100 kHz to 50 MHz in nine ranges. Within limits, its output voltage is held constant at the pre-set level by the RF Leveller. The RF Oscillator is square-wave modulated by the 700 Hz Oscillator.

The output of the RF Oscillator is fed to the Bridge Section. The resultant signal from the bridge then goes to the Tuned Detector section where it is amplified and then demodulated. The 700 Hz audio output of the Detector is amplified in the 700 Hz Amplifier/Buffer section and then applied to the Synchronous Detector section.

Returning to the 700 Hz Oscillator section, its output is also used to trigger the Pulse Generator, whose pulses are fed to the Synchronous Detector. This detector is gated by the pulses, rectifying only the center portion of the square wave signal coming from the bridge/detector/amplifier chain; leading and trailing edges of these square waves are eliminated by the gating circuit constants, avoiding the transients usually associated with these wave-forms.

The final output of the Synchronous Detector is applied to the Meter Driver, and the resultant dc voltage level is indicated on the panel meter.

Referring to the simplified schematic (Figure 8), when the switch is in the DOWN position, the circuit is changed from a bridge to a simple circuit in which the test capacitor is connected between the signal source and the detector. If the Q of the unknown capacitor is greater than 5, the reference voltage at the detector is mainly a function of the reactance of the capacitor.

With the switch in the UP position, a capacitance bridge is formed and at balance the voltage at the detector is only a function of the loss of the test capacitor. It is evident that if the unbalanced voltage obtained with the switch in the DOWN position is adjusted to a specified reference value, the system can be calibrated in terms of the ratio of the two voltages; hence, the Q of the specimen may be read directly.

4.2 Bridge and Compensation Theory

It can be shown that when the bridge circuit of Fig. 9 is balanced, the capacitance of the test specimen equals nC_s, and its Q equals e_r/e_o. C_s is the value of the variable capacitor required to satisfy a susceptive balance of the bridge. If the Q of the test capacitor is finite, the output of the bridge will consist of a residual voltage, e_o, and we define e_r as a reference voltage equal in magnitude to $ne_g/(1+n)^2$.

These relationships are established as follows.

See dwg 830601A following

$$C_s = C_x/n \quad \text{(for susceptive balance)}$$

$$e_o = e_2 - e_1 \qquad (1)$$

$$i_1 = +je_g\omega nC/(1+n)$$

$$i_2 = e_g/\left[r - j(1+n)/\omega C_x\right]$$

$$e_1 = e_g/(1+n)$$

$$e_2 = i_2 Z_x$$

$$e_2 = e_g(r - j/\omega C_x)/\left[r - j(1+n)/\omega C_x\right]$$

Fig. 8

Writing $Q = 1/\omega r C_x$, and substituting the expressions for e_1 and e_2 in (1), we find that as Q approaches infinity,

$$e_o = ne_g/(1+n)^2Q$$

or,

$$Q = \frac{ne_g}{(1+n)^2} \cdot \frac{1}{e_o}$$

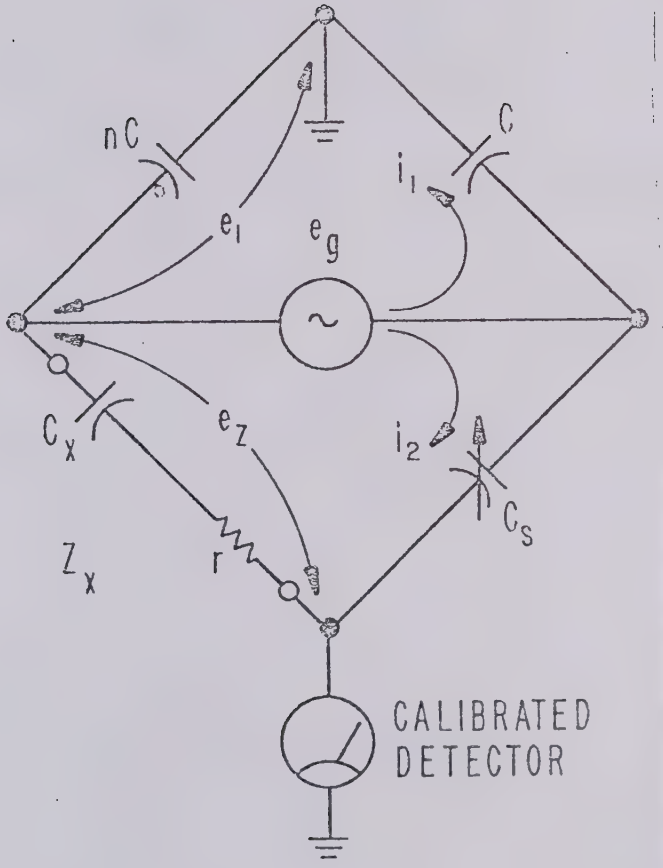


Figure 6. Bridge Circuit

35A
a-173

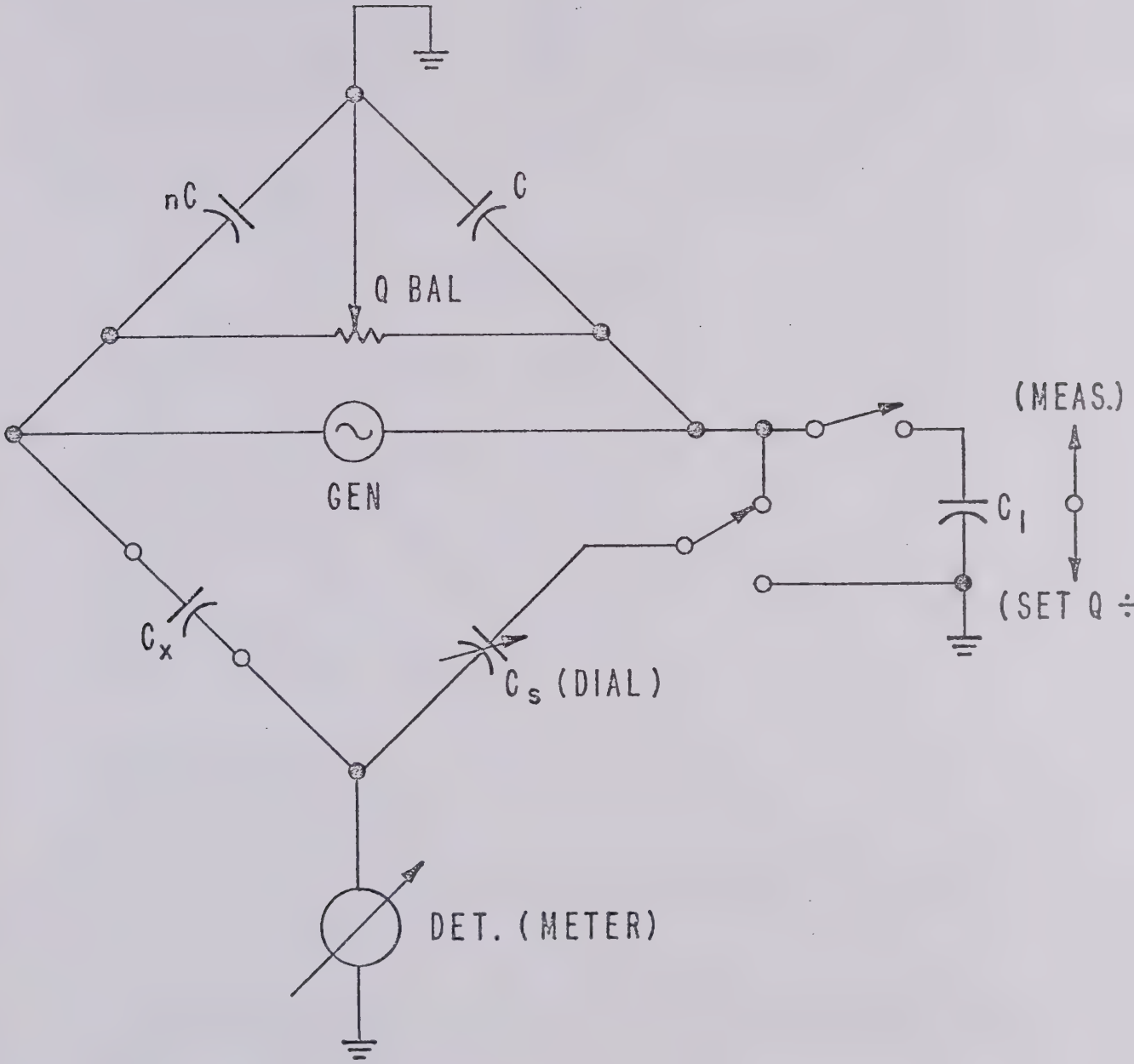


Figure 7. Simplified Schematic

If we initially apply a reference voltage, e_r, to set the gain of the voltmeter/detector for a meter reading of Q = 1, and we make e_r equal to $ne_g/(1+n)^2$, then

$$Q = e_r/e_o$$

If the Q is finite,

$$e_r/e_o = \frac{1 + [(1+n)Q]^2}{(1+n)[1+j(1+n)Q]}$$

If either Q or n is 10 or greater, then $e_r/e_o = Q$, within 0.5%. In the 35A Q-Bridge, the ratio, n, is approximately 18.

Because the system does not require the measurement of absolute voltage levels, the frequency response of the voltmeter/detector need not be exceptionally flat. The ability of the meter to measure ratios can be checked with an attenuator and the internal oscillator. The ranging of the meter (Q) is calibrated using this technique. Details of the calibration procedure are given in the Maintenance Section.

See dwg 830604A following

It is evident that the bridge as shown in Figure 9 is ideal. In practice several factors complicate the successful measurement of Q and capacitance, particularly at the higher frequencies. Specifically, the ratio capacitors, C and nC, have finite Q's; the test arm contains residual resistance and inductance, as do the other arms, but to a lesser extent; and the internal 20 pF standard capacitor, which is needed to initially balance the bridge, has some loss at the higher frequencies.

Fig. 10

The bridge arms are proportioned by a ratio, n, of approximately 18 to 1. This allows the calibrated variable capacitor, C_s, to be sufficiently small so that its series resistance and inductance can be ignored. The conductance of this capacitor is negated by virtue of its three-terminal construction.

The residuals mentioned above are compensated by the following techniques.

Ratio Capacitors

The intrinsic loss of these capacitors is effectively negated with an adjustable and a fixed conductance connected between the two low corners of the bridge and ground. The adjustable element is controlled from the front panel and is designated Q BAL. This adjustment must be made whenever the test frequency is changed.

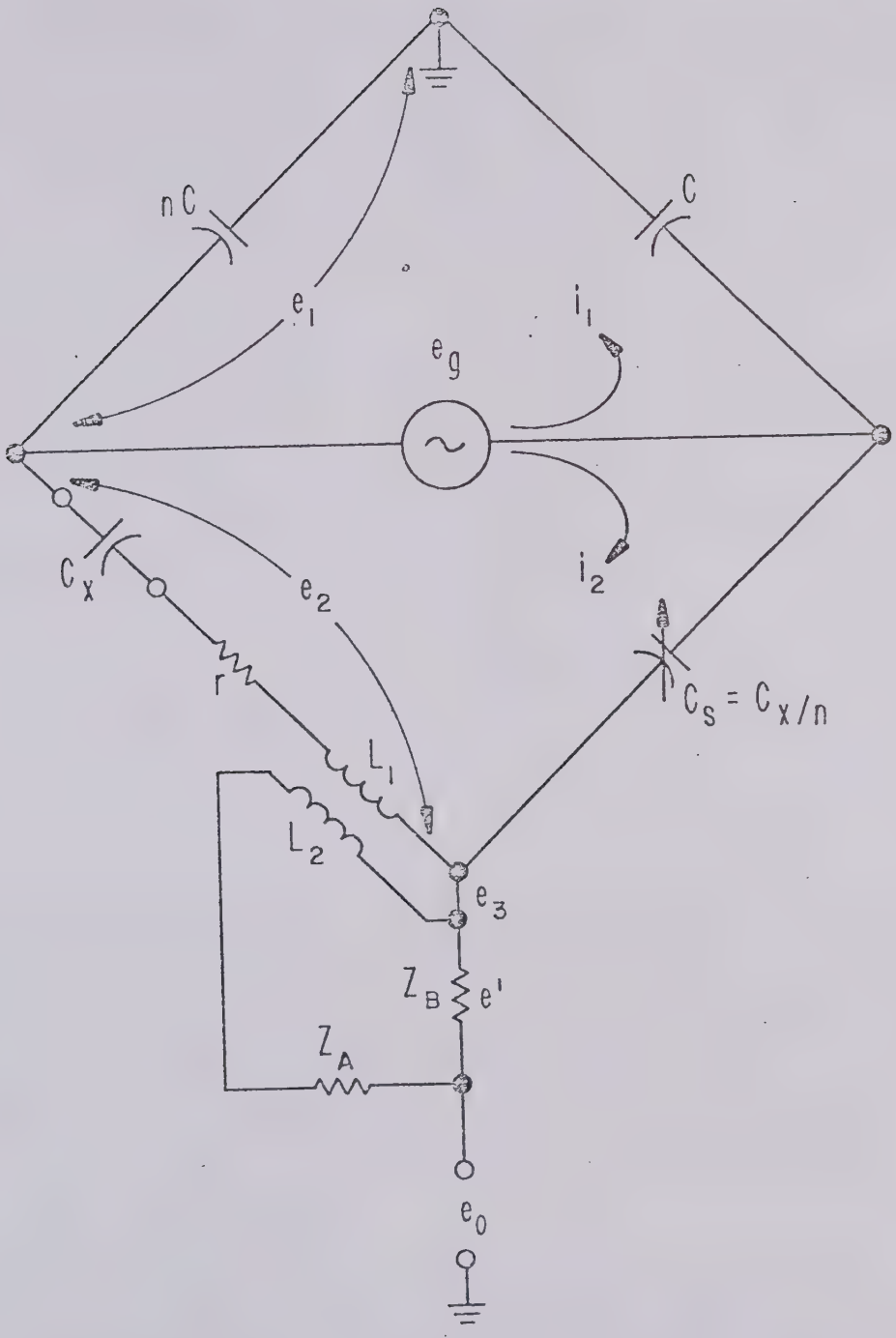


Figure 8. Simplified Bridge Circuit with Compensating Transformer

By reason of construction, the residual inductances associated with the ratio capacitors are sensibly those of the capacitors alone. While the internal inductance of the larger capacitor is less than that of the smaller capacitor (because of the parallel plate construction), their ratio is not the inverse ratio of the capacitors which is needed for complete compensation. Additional compensation is obtained by using two capacitors for the nC arm. The smaller capacitor is connected to a point on the low test post and the combined action of the low post inductance and the capacitor causes the test voltage to rise with frequency at very nearly the rate the voltage is decreased across the larger capacitor owing to the lack of inductive balance in the two ratio capacitors.

Test Terminal Residuals

Compensation for the residual resistance and inductance of the test arm is achieved with a transformer and a frequency-sensitive phase shift network. The transformer primary is a block which supports the high test terminal and the secondary consists of several turns of wire mounted on the supporting block. The phasing network that terminates the secondary uses a combination of resistors and inductors.

An analysis shows that for proper compensation for residual inductance, the mutual inductance must be related to the test arm inductance by,

$$M = L\left(\frac{n}{1+n}\right)$$

Compensation for the residual resistance in the test arm is effected by shifting the phase by an angle θ, where

$$\theta = \tan^{-1}(1+n)/Q$$

where Q is the ratio of the residual reactance to resistance ($\omega L/r$).

The adjustment of the phase shift network is accomplished with a technique we will refer to as stacking. If the capacitance and Q of two capacitors are individually measured, and then the parallel combination is measured, one can readily determine if the residual resistance is influencing the measurements. From the first two measurements, the Q of the combination can be calculated. Should the measurement of the combination disagree with the calculated value, the phasing network needs adjustment. For convenience, the two capacitors should have equal (or nearly equal) values of capacitance and Q. Two such capacitors eliminate the calculation; the capacitance should double and the Q of the parallel combination should equal the individual Q's. Also, in this case the absolute measurement of the Q's need not be accurate.

Loss in 20 pF Standard Capacitor

The Q of the internal 20 pF standard capacitor is sensibly infinite at frequencies below 20 MHz. From 20 to 50 MHz the effective series resistance becomes sufficient to spoil the initial balance of the bridge. Because this is a three-terminal capacitor, a simple resistance-capacitance tee network introduces a negative conductance across the capacitor to raise the Q to a high enough value to permit a good balance. The

effective conductance of the network diminishes to a negligible value at about 20 MHz. The rate of decrease with frequency is arranged to be the inverse of the change in the intrinsic Q of the internal capacitor.

To learn if the initial bridge balance is correct, a measurement can be made with a capacitor of known Q. In general, the lower the Q of this capacitor the smaller the uncertainty of its Q, but the less suitable it is for this purpose. For example, if the Q of the internal 20 pF capacitor decreases from near infinity to 30,000, it will cause an external 20 pF capacitor with a Q of 1000 to read 3.5% high. A 20 pF capacitor with a Q of 5000, however, will read 20% high. Obviously, the higher the Q of the known standard, the better the resolution for adjusting the Q of the internal 20 pF capacitor to approach infinity.

CHAPTER V

TEST AND MAINTENANCE

The Model 35AQ Bridge is designed and built to give years of trouble-free service. However, as with any laboratory instrument of this complexity, it is advisable to establish a periodic test program to check its calibration and general performance at regular intervals. The procedures that follow will enable the user to maintain the instrument in dependable working condition, and require a minimum of test equipment.

Equipment Required

Frequency Counter, 0.1 MHz to 50 MHz

RF Voltmeter, BEC Model 92 Series

DC Power Supply, 0 to 200 vdc

Simpson VOM Model 260

BEC Q Standard 35-8A/1

AC Voltmeter (BEC 93A or equivalent)

5.1 Preliminary Steps

The 35A must be removed from its cabinet before starting the calibration procedure. Remove all the black anodized screws from the front, sides, and rear of the instrument. Remove the black anodized screws from around the bridge terminals on the top surface, being careful not to remove the innermost line of plated screws immediately surrounding the terminal plate.

The major subassemblies of the 35A are located as follows: The Detector circuits are housed in the aluminum enclosure nearest the front panel on the right-hand side of the instrument; the Oscillator circuits are in the enclosure to the rear of the Detector, the Bridge components are in the enclosure immediately below the brass terminal plate on the top of the instrument, while the Power Supply circuits are on the PC board to the left of the instrument.

NOTE

The Bridge section of the 35A is a precision assembly, requiring a very high degree of skill and experience to adjust. The user is strongly urged not to attempt any repair or calibration work on this section, but to return the instrument to the factory if malfunction of Bridge components is suspected.

5.2 Oscillator Frequency Calibration

a. Remove the small coverplate at the rear of the oscillator housing, and turn the PULSE switch on the rear apron to OFF. Connect the frequency counter to the LO-STD Type N connector on the brass top plate of the bridge.

b. Starting with the lowest range (0.1 to 0.2 MHz), adjust the inductance trimmer L103 at the low-frequency end of the range and the capacitance trimmer L103 at the high-frequency end until the dial setting and the frequency counter agree within 2%. The two adjustments will usually interact to some extent, and it will be necessary to go from end to end of the band several times before the frequency is correct at each end.

c. Continue this process through the other bands, consulting Table 1 for the correct controls, and the Location Drawing, Figure 11, to identify them. When all 9 bands have been correctly calibrated, replace the rear cover plate and turn the PULSE switch back to ON. Be sure that all the screws for the cover plate are well tightened.

5.3 Detector Tracking Adjustment

a. Remove the small cover plate on the top of the detector housing. Set the MHZ switch to the 0.1 - 0.2 MHz position.

b. With the 100-300 Q RANGE switch button depressed, unbalance the bridge to obtain an 'on-scale' reading on the meter.

c. Set the FREQUENCY control to one dial division in from the low-frequency end (0.105 MHz).

d. Adjust inductance trimmer L305 (see Location drawing, Figure 12, for identification) for the lowest meter reading (minimum Q).

e. Adjust FREQUENCY control to one dial division in from the high-frequency end of the band, and adjust C312 for the lowest meter reading.

f. Repeat each of these two adjustments as required until good tracking is obtained.

g. Repeat this procedure on the remaining 8 bands, following the steps in Table II. Then replace the cover plate and tighten the mounting screws.

5.4 Test Level Calibration

a. Set MHz switch to the 0.2 - 0.4 MHz position, FREQUENCY control to 300 kHz, CAPACITANCE control to 20 pF, and the Q BAL controls to maximum ccw positions. Turn the PULSE switch to OFF.

TABLE I

Band	Frequency	Adjust	Frequency	Adjust
1	0.1 MHz	L103	0.2 MHz	C103
2	0.2 MHz	L104	0.4 MHz	C104
3	0.4 MHz	L105	0.8 MHz	C105
4	0.8 MHz	L106	1.6 MHz	C106
5	1.6 MHz	L107	3.0 MHz	C108
6	3.0 MHz	L108	6.0 MHz	C109
7	6.0 MHz	L109	12 MHz	C110
8	12 MHz	L110	24 MHz	C111
9	24 MHz	L111	50 MHz	C112

See Dwg 830600 A following

Figure 9. Location Drawing

ZONE	REV.

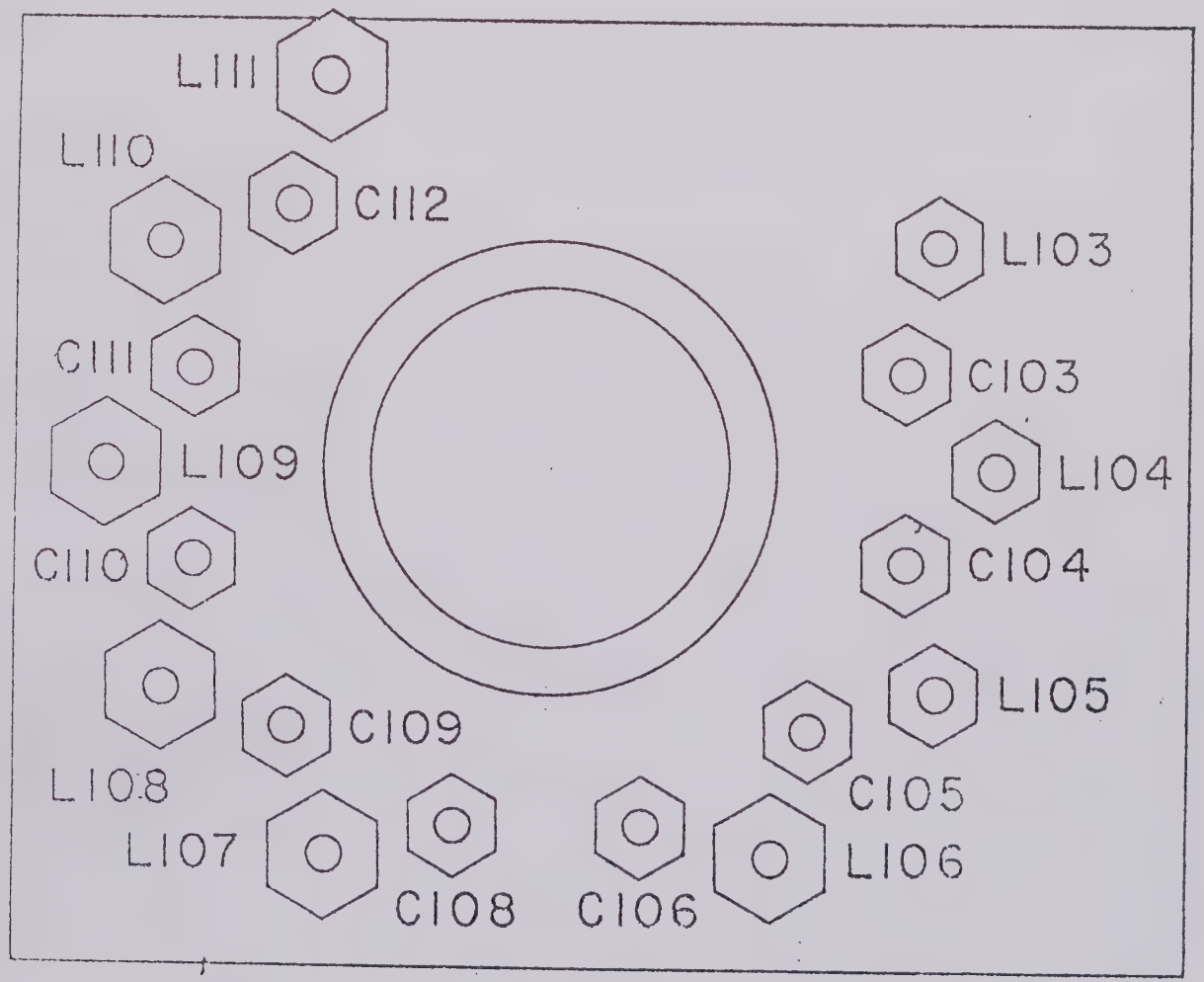
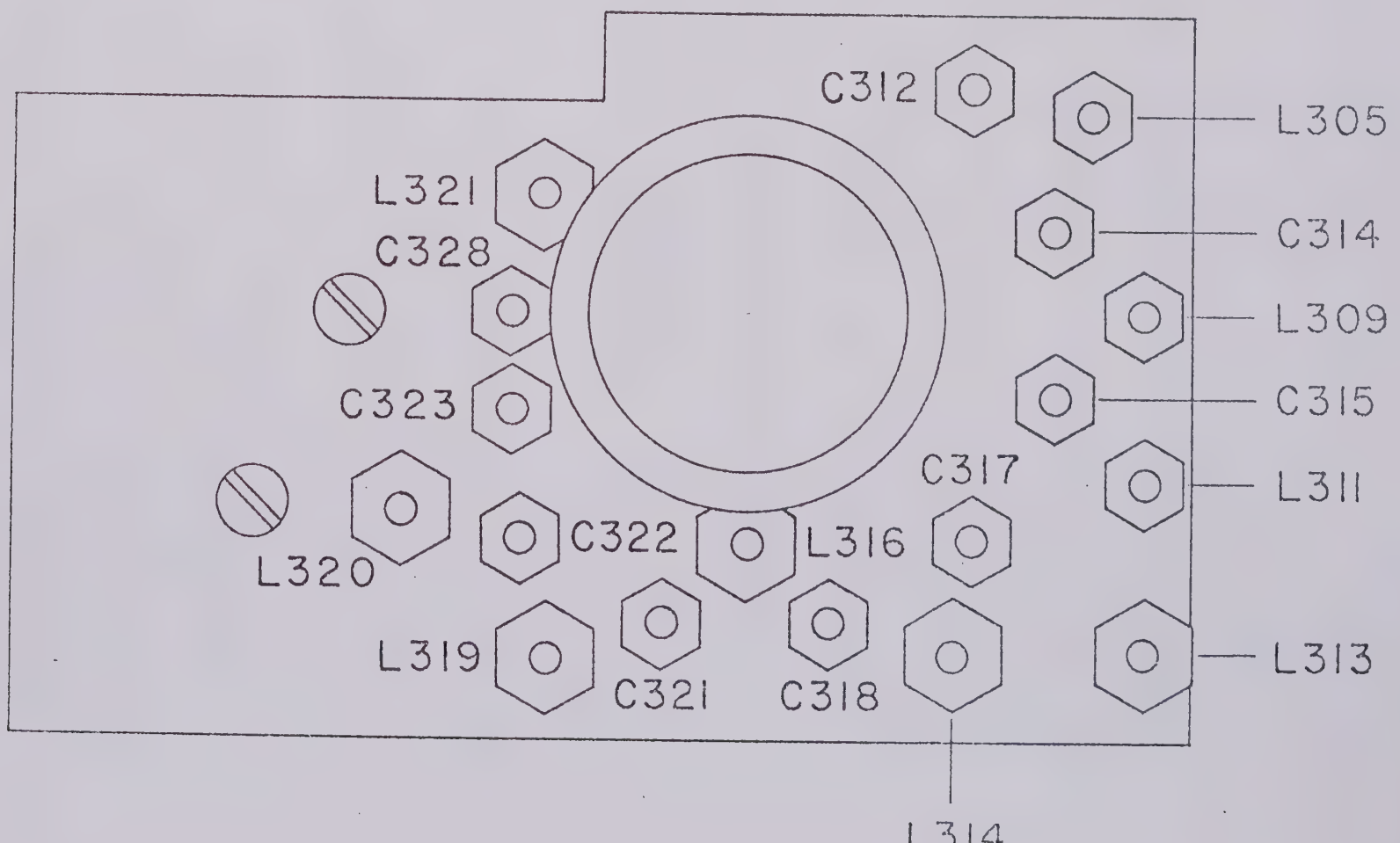

L111
L110
C112
L103
C111
C103
L109
L104
C110
C104
L105
C109
L108
C105
L107
L106
C108
C106

TABLE II

Band	Frequency	Adjust	Frequency	Adjust
1	0.105 MHz	L305	0.195 MHz	C312
2	0.21 MHz	L309	0.39 MHz	C314
3	0.425 MHz	L311	0.775 MHz	C315
4	0.85 MHz	L313	1.55 MHz	C317
5	1.55 MHz	L314	2.95 MHz	C318
6	3.10 MHz	L316	5.90 MHz	C321
7	6.20 MHz	L319	11.8 MHz	C322
8	12.5 MHz	L320	23.5 MHz	C323
9	25.0 MHz	L321	49.0 MHz	C328

See dwg 830599 A following

Figure 10. Location Drawing


C312
L305
L321
C314
C328
L309
C323
C315
C317
L311
L320
C322
L316
L319
C321
C318
L313
L314

b. Connect the RF voltmeter from the LO TEST post to ground.

c. Set the TEST LEVEL control to 10 mV and read the RF voltmeter. If it does not indicate 10 mV, adjust R477 on the Power Supply PC Board for a correct reading. (See Figure 13 to locate this and other controls on this board.)

d. Set the TEST LEVEL control to 30 mV and read the RF voltmeter. Adjust R475 as needed to obtain a correct reading.

e. Repeat steps 'c' and 'd' as necessary to achieve errors of less than ± 2 mV at any point on the TEST LEVEL range.

f. Set the MHZ switch to the 24 - 50 MHz position, and the TEST LEVEL control to 20 mV.

g. Measure the test level at all frequencies between 24 and 50 MHz. If the observed error is greater than ± 2 mV at any frequency, set the FREQUENCY control to the point of maximum error and adjust C131 for a reading of 20 mV.

NOTE: Access to C131 is obtained by removing the cover plug at the top of the right-hand side of the Oscillator housing.

5.5 Q Ranging Calibration

a. Locate the coaxial cable running horizontally from the top front of the Bridge housing to the left side of the Detector enclosure, immediately behind the top of the front panel. Disconnect this cable from the Detector input (J301).

b. Connect a 30 dB G.R. attenuator, in series with an adjustable attenuator of 70 dB maximum (50Ω), between the LO STD Type N connector on the Bridge top plate and the Detector input connector, J301.

c. Turn the PULSE switch to ON, and set the FREQUENCY control to 300 kHz. Set the Q RANGE switch for the 100 - 300 range.

d. Set the adjustable attenuator for 40 dB, then adjust the Q DIVIDER control for an 'on-scale' meter reading.

e. Adjust R503 on the Sync Rectifier PC board for a maximum leftward deflection on the meter (lowest Q).

NOTE: The Sync Rectifier PC board is mounted vertically on the left wall of the cabinet; R503 is the rearmost of the two potentiometers on this board.

f. Remove the input coaxial cable from the Sync Rectifier (J402). This is the heavy grey cable in the front group, fourth terminal from the front edge.

g. Short the panel meter terminals together with a small clip lead and adjust the meter's mechanical zero screw for a reading of infinite Q (∞).

h. Remove the jumper from the meter terminals and adjust R516 (front potentiometer) on the Sync Rectifier board for a reading of infinite Q (∞). Replace the input cable to the Sync Rectifier J402.

i. Connect the AC voltmeter to the input of the 700 Hz amplifier (P401). This may be done by clipping the voltmeter lead to the junction of the 681 Ω resistor and the 0.01 μF capacitor located at the front right corner of the Power Supply board, immediately behind the right-hand section of the Q RANGE switch.

j. Adjust the Q DIVIDER control for a reading of 6 mV on the AC voltmeter. Disconnect the voltmeter once this has been done.

k. Make the Q Range adjustments through the positions of the switch in accordance with Table III following. Refer to Figure 13 to locate the various trimmers on the Master Board.

l. Remove the attenuators and reconnect the Bridge cable to the Detector. This completes the Q Ranging calibration.

5.6 Internal Bias Check

a. Connect the VOM, set on the 250 vdc range, between the HI and LO Monitor terminals on the panel. Set the INTERNAL BIAS switch to the 0 - 100 v position.

b. Turn the ADJ control slowly from the ccw to the cw position while watching the VOM reading. The voltage should increase smoothly from 0 to 100 volts dc.

c. Set the INTERNAL BIAS switch to the 0 - 10 v position, and the VOM to the 50 vdc range. Repeat the test above.

d. Connect the VOM between the HI and LO TEST connectors on the bridge plate and verify that the meter reads the same as when it was connected to the Monitor jacks on the panel.

5.7 External Bias Check

a. Connect the shorting bar between the LO and Ground EXTERNAL BIAS terminals on the panel. Connect the VOM between the bridge HI and LO TEST terminals, and set to the 250 vdc range. Connect the dc power supply between the HI and LO EXTERNAL BIAS terminals on the panel. Set the INTERNAL BIAS switch to the EXT position.

b. Set the power supply to 200 vdc, and verify that the VOM reads the same.

c. Shift the shorting bar to the HI and Ground EXTERNAL BIAS terminals. Connect the positive power supply lead to the Ground terminal and the negative lead to the LO terminal. Set the output of the power supply to 50 vdc and verify that the VOM reading agrees. Remove the power supply and VOM.

TABLE III

Q Range	Attenuator Setting	Adjustment	Adjust for Q =
100-300	40dB	R442	100
100-300	46dB	R412	200
1-3	0dB	R440	1
3-10	10dB	R435	3.16
10-30	20dB	R426	10
30-100	30dB	R420	31.6
300-1K	50dB	R414	316
1K-3K	60dB	R409	1K
3K-10K	70dB	R405	3.16K

See dwg 830593 following

Figure 11. Q Ranging Adjustment Location

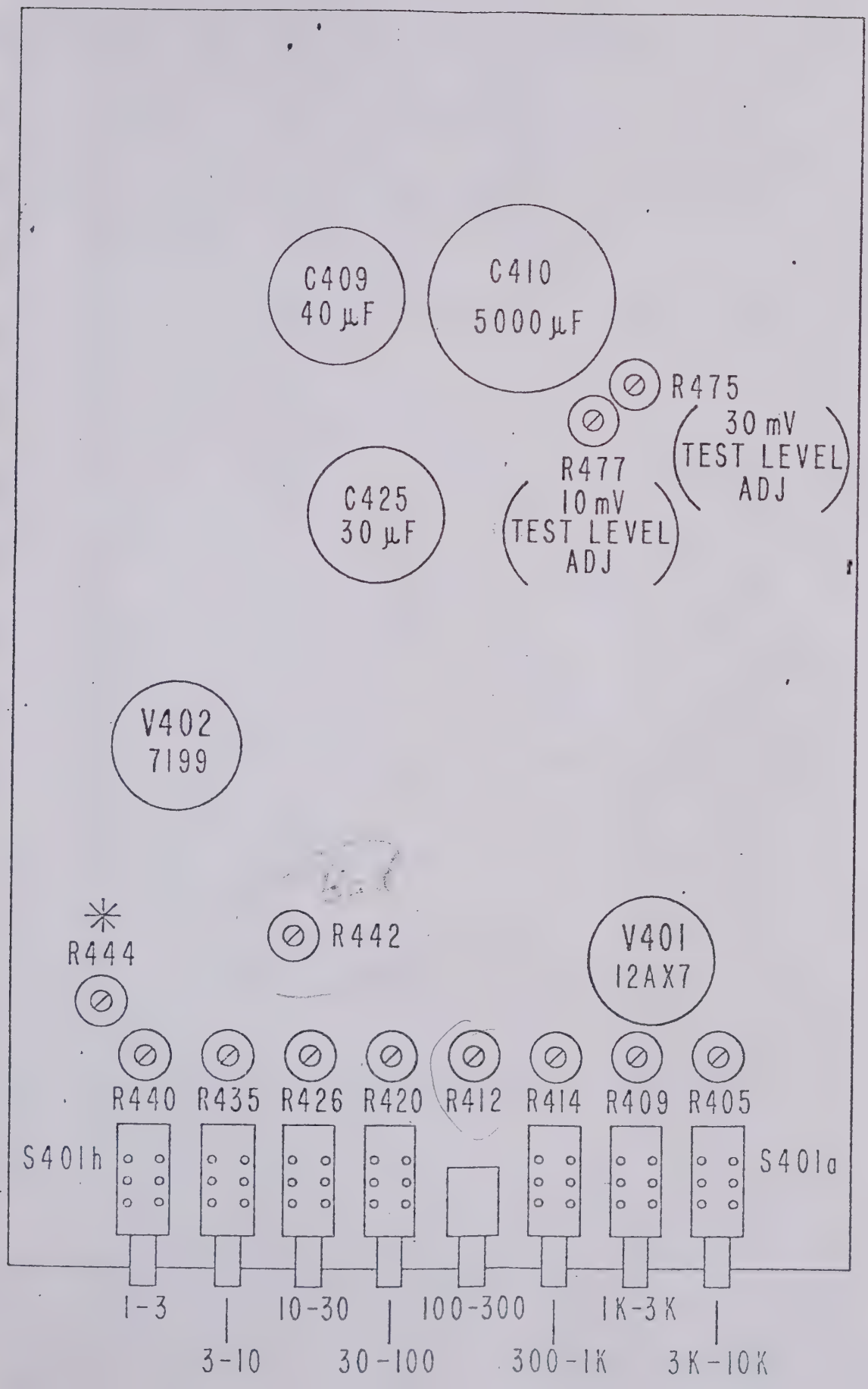

C409
40 µF
C410
5000 µF
R475
30 mV
TEST LEVEL
ADJ
R477
10 mV
TEST LEVEL
ADJ
C425
30 µF
V402
7199
✳
R444
R442
V401
12AX7
R440
R435
R426
R420
R412
R414
R409
R405
S401h
S401a
1-3
3-10
10-30
30-100
100-300
300-1K
1K-3K
3K-10K

TABLE OF REPLACEABLE PARTS

Reference		Description		BEC Part No.
C101	Capacitor, Fixed	0.01 µF 10% 200V	Sprague 192P10392	234027
C102	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C103	" , Var.	0.25 - 8 pF	Jackson 408	279112
C104	" "	"	"	"
C105	" "	"	"	"
C106	" "	"	"	"
C107	" , Fixed	3.3 pF ±0.25 pF	CRL TCZ-3R3	224105
C108	" Var.	0.25 - 8 pF	Jackson 408	279112
C109	" "	"	"	"
C110	" "	"	"	"
C111	" "	"	"	"
C112	" "	"	"	"
C113	" , Fixed	0.007 µF 20% 500V	Erie 2499-003	227103
C114	" , Var.	10 - 100 pF	Hammarlund VU20 (Mod)	275146
C115	" , Fixed	0.22 µF 20% 50V	Sprague 5C023224X0500B	224129
C116	" "	0.0068 µF 5% 200V	Sprague 192P8252	234059
C117	" "	0.001 µF 10% 200V	Sprague 192P10292	234039
C118	" "	4.7 pF ± 0.5 pF	CRL TCZ-4R7	220111
C119	" "	0.004 µF 20% 500V	Erie 2499-003	227104
C120	" "	1000 pF 20% 500V	Erie 2499-003	227105
C121	" "	39 pF 5% 500V	Arco DM 15-390J	200025
C122	" "	33 pF 5% 500V	Arco DM 15-330J	200049
C123	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C124	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C125	" "	0.047 µF 5% 200V	Sprague 192P47352	234026
C126	" "	0.1 µF 10% 200V	Sprague 192P104492	230116
C127	" "	0.0047 µF 10% 200V	Sprague 192P47292	234074
C128	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C129	" "	1.0 µF 20% 200V	M. I. W2-105	235026
C130	" Var.	2 - 10 pF	Jackson 5640 PC/T	279118
C131	" "	0.25 - 8 pF	Jackson 408	279112
C132	" , Fixed	0.007 µF 20% 500V	Erie 2499-003	227103
C133	" "	"	"	"
C134	" "	Sprague 192P20252	Sprague 192P20252	234024
C135	" "	1.0 µF 10% 35V	Kemet K1C35K	283187
C136	" "	0.015 µF 5% 200V	Sprague 192P15352	234063
C137	" "	0.0056 µF 5% 200V	Sprague 192P56252	234076
C138	" "	0.0015 µF 5% 200V	Sprague 192P15252	234067
C139	" "	430 pF 1% 500V	Arco DM 15431F	200037
C140	" "	120 pF 1% 500V	Arco DM 15E121F	200051
C141	" "	22 pF 5% 500V	Arco DM 15E220J	200060
C142	" "	0.01 µF 10% 200V	Sprague 192P10392	234027

Reference		Description		BEC Part No.
C301	Capacitor, Fixed	300 pF 5% 500V	Arco DM 15301J	200034
C302	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C303	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C304	" "	0.0068 µF 10% 200V	Sprague 192P68292	234044
C305	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C306	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C307	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C308	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C309	" "	0.22 µF 20% 50V	Sprague5C023224X0500B3	224128
C310	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C311	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C312	" , Var.	0.25 - 8 pF	Jackson 408	279112
C313	" , Fixed	0.022 µF 20% 200V	Sprague 192P22302	234003
C314	" , Var.	0.25 - 8 pF	Jackson 408	279112
C315	" "	0.25 - 8 pF	Jackson 408	279112
C316	" , Fixed	0.01 µF 10% 200V	Sprague 192P10392	234027
C317	" , Var.	0.25 - 8 pF	Jackson 408	279112
C318	" "	"	"	"
C319	" , Fixed	10 pF 5% 500V	Arco DM 10-C100	200022
C320	" "	0.22 µF 20% 50V	Sprague5C023224X0500B3	224128
C321	" , Var.	0.25 - 8 pF	Jackson 408	279112
C322	" "	"	"	"
C323	" "	"	"	"
C324	" , Fixed	3.3 pF ± 0.25 pF	CRL TCZ 3R3	224105
C325	" "	2 pF 5% 500V	Arco DM 10-C020	200042
C326	" , Var.	2 - 10 pF	Jackson 5640-PC/T	279118
C327	" , Fixed	3 pF 5% 500V	Arco DM 10-C030	200069
C328	" , Var.	0.25 - 8 pF	Jackson 408	279112
C329	" , Fixed	0.007 µF 20% 500V	Erie 2499-003	227103
C330	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C331	" "	5 µF 50V	Sprague TE 1303	283143
C332	" , Var.	10 - 100 pF	Hamm. VU-20 (Mod.)	275150
C333	" , Fixed	0.1 µF 10% 200V	Sprague 192P10492	230116
C334	" "	"	"	"
C335	" "	"	"	"
C336	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C337	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C338	" "	0.22µF 20% 200V	M. I. W2-224	235025
C339	" "	0.47 µF 20% 50V	Rep. MU28BX474M	224131
C340	" "	100 pF 5% 500V	Arco DM 15-F101J	200001
C341	" "	0.056 µF 20% 200V	M. I. W2-563	236006
C342	" "	0.22 µF 20% 50V	Sprague5C023224X0500B3	224128
C343	" "	0.007 µF 20% 500V	Erie 2499-003	227103
C344	" "	0.22 µF 20% 50V	Sprague5C023224X0500B3	224128
C345	" "	5 µF 50V	Sprague TE 1303	283143
C346	" "	0.1 µF 20% 100V	M. I. J1-104	236011

Reference		Description		BEC Part No.
C347	Capacitor, Fixed	56 pF 5% 500V	Arco DM 15-560J	200030
C348	" "	100 pF 5% 500V	Arco DM 15-F101J	200001
C349	" "	5 µF 50V	Sprague TE 1303	283143
C350	" "	470 pF 5% 500V	Arco DM 15-471J	200028
C351	" "	4.7 µF 20% 20V	Kemet T360B475M020AS	283197
C401	Capacitor, Fixed	0.01 µF 10% 200V	Sprague 192P10392	234027
C402	" "	10 µF 6V	Sprague TE-1087	283130
C403	" "	0.056 µF 20% 200V	M. I. W2-563	236006
C404	" "	10 µF 6V	Sprague TE-1087	283130
C405	" "	5 µF 150V	Sprague TE-1504	283173
C406	" "	0.022 µF 10% 200V	Sprague 192P22392	230101
C407	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C408	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C409	" "	40 µF +50% -10% 450V	Mallory FP-146	283203
C410	" "	5000 µF +150% -10%	Mallory FP-060.6 25V	283202
C411	" "	0.022 µF 2% 500V	G.I. RDM42-FD223G03	204104
C412	" "	0.047 µF 10% 400V	Sprague 192P47394	234047
C413	" "	0.0022 µF 5% 200V	Sprague 192P22252	234069
C414	" , Var.	1400 - 3055 pF	Arco 30 - 315	275508
C415	" , Fixed	0.001 µF 10% 200V	Sprague 192P10292	234039
C416	" "	0.001 µF 500V	Erie 831Z5U0102P	224114
C417	" "	5 µF 20% 200V	M. I. W2-505	236003
C418	" "	5 µF 150V	Sprague TE-1504	283173
C419	" "	0.001 µF 500V	Erie 831Z5U0102P	224114
C420	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C421	" "	0.001 µF 500V	Erie 831Z5U0102P	224114
C422	" "	"	"	"
C423	" "	0.047 µF 5% 200V	Sprague 192P47352	234026
C424	" "	5 µF 150V	Sprague TE-1504	283173
C425	" "	30 µF +100% -10% 350V	Mallory FP-135V	283161
C426	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C427	" "	5 µF 50V	Sprague TE-1303	283143
C428	" "	0.0047 µF 10% 200V	Sprague 192P47292	234074
C429	" "	0.1 µF 10% 200V	Sprague 192P10492	230116
C430	" "	0.22 µF 5% 200V	Sprague 192P22452	234078
C431	" "	0.027 µF 2% 500V	G.I. RDM42-FD273G03	204103
C432	" , Var.	1400 - 3055 pF	Arco Type 30 315	275508
C433	" , Fixed	0.01 µF 5% 200V	Sprague 192P10352	234061
C434	" "	1 µF 10% 35V	Kemet K1C35K	283187

Reference		Description		BEC Part No.
C501	Capacitor, Fixed	0.0068 µF 10% 200V	Sprague 192P68292	234044
C502	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C503	" "	"	"	"
C504	" "	2000 pF 5% 500V	Arco DM 20E-202J	201201
C505				
C506	" "	0.0033 µF 10% 200V	Sprague 192P33292	230119
C507	" "	330 pF 1% 500V	Arco DM 15-F331F	200033
C508	" "	"	"	"
C509	" "	25 µF 25V	Sprague TE-1207	283173
C510	" "	0.01 µF 10% 200V	Sprague 192P10392	234027
C511	" "	"	"	"
C512	" "	0.1 µF 20% 100V	M.I. J1-104	236011
C513	" "	"	"	"
C514	" "	"	"	"
C515	" "	100 µF 15V	Sprague TE-1162	283144

Reference		Description		BEC Part No.
R101	Resistor, Fixed	15 kΩ 1/2W 5%	AB EB	301115
R102	" "	"	"	"
R103	" "	"	"	"
R104	" "	"	"	"
R105	" "	22 Ω 1/2W 5%	"	301047
R106	" "	330 kΩ 1/2W 5%	"	301147
R107	" "	68 kΩ 1/2W 5%	"	301131
R108	" "	47 Ω 1/2W 5%	"	301055
R109	" "	47 Ω 1/2W 5%	"	301055
R110	" "	10 kΩ 1/2W 5%	"	301111
R111	" "	500 Ω 2W 5%	Sprague 240E5015	310103
R112	" "	10 kΩ 1/2W 5%	AB EB	301111
R113	" "	47 kΩ 1/2W 5%	"	301127
R114	" "	39 kΩ 1/2W 5%	"	301125
R115	" "	180 Ω 1/2W 5%	"	301069
R116	" "	470 kΩ 1/2W 5%	"	301151
R117	" "	"	"	"
R118	" "	10 kΩ 1/2W 5%	"	301111
R119	" "	"	"	"
R120	" "	1 kΩ 1/2W 5%	"	301087
R121	" "	15 kΩ 1/4W 5%	AB CB	300110
R122	" "	2.2 kΩ 1/2W 5%	AB EB	301095

Reference		Description		BEC Part No.
R301	Resistor, Fixed	200 kΩ 1/2W 5%	AB EB	301142
R302	" "	820 kΩ 1/2W 5%	"	301157
R303	" "	"	"	301157
R304	" "	1 MΩ 1/2W 1%	T. I. MC60D	326700
R305	" "	1 kΩ 1/2W 5%	AB EB	301087
R306	" "	100 Ω 1/2W 5%	"	301063
R307	" "	22 Ω 1/2W 5%	"	301047
R308	" "	2 kΩ 2W 5%	Sprague 240E2025	310109
R309	" "	1 kΩ 1/2W 5%	AB EB	301087
R310	" "	191 kΩ 1/2W 1%	T.I. MC60D	326517
R311	" "	178 kΩ 1/2W 1%	"	326514
R312	" "	191 kΩ 1/2W 1%	"	326517
R313	" "	1 MΩ 1/2W 5%	AB EB	301159
R314	" "	"	"	"
R315	" "	2 kΩ 2W 5%	Sprague 240E2025	310109
R316	" "	33 kΩ 1/2W 5%	AB EB	301123
R317	" "	15 kΩ 1/2W 5%	"	301115
R318	" "	47 Ω 1/4W 5%	AB CB	300050
R319	" "	100 Ω 1/2W 5%	AB EB	301063
R320	" "	4.7 kΩ 1/2W 5%	"	301103
R321	" "	1 kΩ 1/2W 5%	"	301057
R322	" "	270 Ω 1/2W 5%	"	301073
R323	" "	680 kΩ 1/4W 5%	AB CB	300150
R324	" "	10 kΩ 1/4W 5%	"	300106
R325	" "	27 kΩ 1/4W 5%	"	300116
R326	" "	3 Ω 1/2W 5%	AB EB	301504
R327	" "	500 Ω 2W 5%	Sprague 240E5015	310103
R328	" "	"	"	"
R329	" "	1 kΩ 2W 5%	Sprague 240E1025	310106
R330	" "	47 Ω 1/4W 5%	AB CB	300050
R331	" "	10 kΩ 1/2W 5%	AB EB	301111
R332	" "	180 kΩ 1/4W 5%	AB CB	300136
R333	" "	10 kΩ 1/2W 5%	AB EB	301111
R334	" "	27 kΩ 1W 5%	AB GB	302135
R335	" "	47 kΩ 1/4W 5%	AB CB	300122
R336	" "	100 kΩ 1/4W 5%	AB CB	300130
R337	" "	1.3 kΩ 1/2W 5%	AB EB	301090
R338	" "	1.6 kΩ 1/2W 5%	"	301092
R339	" "	1 kΩ 2W 5%	Sprague 240E1025	310106
R340	" "	220 Ω 1/2W 5%	AB EB	301071
R341	" "	15 kΩ 1/2W 5%	"	301115
R342	" "	301 Ω 1/2W 1%	T.I. MC60D	340176
R343	" "	18 Ω 1/2W 5%	AB EB	301045

Reference		Description		BEC Part No.
R401	Resistor, Fixed	681 Ω 1/2W 1%	T. I. MC60D	326086
R402	" "	68 kΩ 1/2W 5%	AB EB	301131
R403	" "	180 kΩ 1/2W 5%	"	301141
R404	" "	270 Ω 1/2W 5%	"	301073
R405	" Var.	1 kΩ 1/2W 10%	AB SV1021	311250
R406	" , Fixed	390 kΩ 1/2W 5%	AB EB	301149
R407	" "	22 kΩ 1/2W 5%	"	301119
R408	" "	1 MΩ 1/2W 5%	"	301159
R409	" Var.	20 kΩ 1/2W 10%	AB SV2031	311248
R410	" , Fixed	390 kΩ 1/2W 5%	AB EB	301149
R411	" "	5.1 kΩ 1/2W 5%	"	301104
R412	" Var.	200 kΩ 1/2W 10%	AB SV2041	311252
R413	" , Fixed	825 kΩ 1/4W 1%	T. I. MC55D	325690
R414	" Var.	20 kΩ 1/2W 10%	AB SV2031	311248
R415	" , Fixed	82.5 kΩ 1/4W 1%	T.I. MC55D	325475
R416	" "	1 MΩ 1/2W 5%	AB EB	301159
R417	" "	10 kΩ 1/2W 5%	"	301111
R418	" "	9.09 kΩ 1/4W 1%	T.I. MC55D	325407
R419	" "	10 kΩ 1/2W 5%	AB EB	301111
R420	" Var.	20 kΩ 1/2W 10%	AB SV2031	311248
R421	" , Fixed	3 Ω 7.5W 1%	Dale RHS	312123
R422	" "	"	"	"
R423	" "	22 Ω 1/2W 5%	AB EB	301047
R424	" "	330 kΩ 1/2W 5%	"	301147
R425	" "	5.6 kΩ 1/2W 5%	"	301105
R426	" , Var.	20 kΩ 1/2W 10%	AB SV2031	311248
R427	" , Fixed	2 kΩ 5W 5%	Sprague 243E2025	310276
R428	" "	1 kΩ 5W 5%	Sprague 234E1025	310260
R429	" "	33 kΩ 1W 5%	AB GB	302248
R430	" "	27 kΩ 1/2W 5%	AB EB	301121
R431	" "	91 kΩ 1/2W 5%	"	301134
R432	" "	27 kΩ 1/2W 5%	"	301121
R433	" "	1 kΩ 5W 5%	Sprague 234E1025	310260
R434	" "	2.2 MΩ 1/2W 5%	AB EB	301167
R435	" VAR	20 kΩ 1/2W 10%	AB SV2031	311248
R436	" "	1 kΩ 1/2W 5%	AB EB	301087
R437	" "	30 kΩ 1/2W 5%	"	301122
R438	" "	120 kΩ 1/2W 5%	"	301137
R439	" "	3.3 kΩ 1/2W 5%	"	301099
R440	" Var.	20 kΩ 1/2W 10%	AB SV2031	311248
R441	" , Fixed	680 kΩ 1/2W 5%	AB EB	301155
R442	" VAR	~~10 kΩ 1/2W 5%~~ 500K	AB SV5041	~~301111~~ 311253
R443	" "	100 kΩ 1/2W 5%	"	301135
R444	" , Var.	1 MΩ 1/2W 10%	AB SV1051	311249
R445	" , Fixed	9.53 kΩ 1/4W 1%	T.I. MC55D	325408
R446	" "	49.9 kΩ 1/4W 1%	"	325472

Reference	Description			BEC Part No.
R447	Resistor, Fixed	180 kΩ 1/2W 5%	AB EB	301141
R448	" "	150 kΩ 1/2W 5%	"	301139
R449	" "	62 kΩ 1/2W 5%	"	301130
R450	" "	15 kΩ 2W 5%	AB HB	304115
R451	" "	910 kΩ 1/2W 5%	AB EB	301158
R452	" "	2.2 MΩ 1/2W 5%	"	301167
R453	" "	47 kΩ 1/2W 5%	"	301127
R454	" "	150 kΩ 1/2W 5%	"	301139
R455	" "	1.2 kΩ 1/2W 5%	"	301089
R456	" "	100 kΩ 1/2W 5%	"	301135
R457	" "	1 MΩ 1/2W 5%	"	301159
R458	" "	390 kΩ 1/2W 5%	"	301149
R459	" "	4.7 kΩ 1/2W 5%	"	301103
R460	" "	1 MΩ 1/2W 5%	"	301159
R461	" "	4.7 kΩ 1/2W 5%	"	301103
R462	" "	12 kΩ 1/2W 5%	"	301113
R463	" "	390 kΩ 1/2W 5%	"	301149
R464	" "	3.9 kΩ 1/2W 5%	"	301101
R465	" "	390 kΩ 1/2W 5%	"	301149
R466	" "	120 kΩ 1/2W 5%	"	301137
R467	" "	270 kΩ 1/2W 5%	"	301145
R468	" "	12 kΩ 1/2W 5%	"	301113
R469	" "	390 kΩ 1/2W 5%	"	301149
R470	" "	820 kΩ 1/2W 5%	"	301157
R471	" "	10 kΩ 1/2W 5%	"	301111
R472	" "	390 kΩ 1/2W 5%	"	301149
R473	" "	1 MΩ 1/2W 5%	"	301159
R474	" "	470 Ω 1/2W 5%	"	301079
R475	" "	1 MΩ 1/2W 10%	AB SV1051	311249
R476	" "	1 MΩ 1/2W 5%	AB EB	301159
R477	" Var.	50 kΩ 1/2W 10%	AB SV5031	311278
R478	" , Fixed	120 kΩ 1/2W 5%	AB EB	301137
R501	Resistor, Fixed	68 kΩ 1/2W 5%	AB EB	301131
R502	" "	150 kΩ 1/2W 5%	"	301139
R503	" Var.	500 kΩ 1/2W 10%	AB SV5051	311253
R504	" , Fixed	12 kΩ 1/2W 5%	AB EB	301113
R505	" "	"	"	"
R506	" "	100 kΩ 1/2W 5%	"	301135
R507	" "	"	"	"
R508	" "	470 kΩ 1/2W 5%	"	301151
R509	" "	"	"	"
R510	" "	47 kΩ 1/2W 5%	"	301127
R511	" "	"	"	"

Reference		Description		BEC Part No.
R512	Resistor, Fixed	100 kΩ 1/2W 5%	AB EB	301135
R513	" "	10 MΩ 1/2W 5%	"	301183
R514	" "	"	"	"
R515	" "	470 kΩ 1/2W 5%	AB EB	301151
R516	" , Var.	1 MΩ 1/2W 10%	AB SV1051	311249
R517	" , Fixed	470 kΩ 1/2W 5%	AB EB	301151
R518	" "	910 kΩ 1/2W 5%	"	301158
R519	" "	"	"	"
R520	" "	2.2 kΩ 1/2W 5%	"	301095
R521	" "	24.3 kΩ 1/2W 1%	T. I. MC60D	340405

INDUCTORS

L101	Inductor, Fixed	15 µH 10%	Nytronics WEE 2.2	400197
L102	" "	24 mH 5%	Stanwyck 624000	400208
L103	" Var.	5.3 - 8.2 mH	CTC 3338-30	400212
L104	" "	1.27 - 1.9 mH	CTC 3338-27	400185
L105	" "	625 - 950 UH	CTC 3338-25	400186
L106	" "	325 - 455 µH	CTC 3642-44	400187
L107	" "	68 - 96 µH	CTC 3642-36	400188
L108	" "	22.4 - 31.6 µH	CTC 3642-30	400189
L109	" "	3.2 - 7.2 µH		400222
L110	" "	0.8 - 1.8 µH		400223
L111	" "	0.25 - 0.34 µH		400225
L112	" Fixed	15 mH 5%	Stanwyck 615000	400181
L113	" "	3.9 mH 5%	Stanwyck 539000	400201
L114	" "	560 µH 5%	Stanwyck Dink-560	400183
L115	" "	6.8 µH 10%	Nytronics WEE-6.8	400177
L116	" "	5.6 mH		400226
L117				
L118	" "	15 µH 10%	Nytronics WEE-15	400175
L119	" "	10 mH 5%	Stanwyck Dink-10,000	400143
L120	" "	15 µH 10%	Nytronics WEE-15	400175
L121	" "	1000 µH 5%	Stanwyck Dink-1000	400135
L122	" "	10 mH 5%	" " -10,000	400143
L123	" "	390 µH 5%	" " -390	400179
L124	" "	4.7 µH 10%	" " -4.7	400144
L125	" "	2.2 µH 10%	" " -2.2	400178
L126	" "	"	" "	"
L127	" "	15 µH 10%	Nytronics WEE-15	400175
L128	" "	4.7 µH 10%	Stanwyck Dink-4.7	400144
L129	" "	22 µH 10%	Nytronics WEE-22	400073

Reference			Description		BEC Part No.
L301	Inductor,	Fixed	10 mH 5%	Stanwyck Dink-10,000	400143
L302	"	"	24 mH		400208
L303	"	"	10 mH 5%	Stanwyck Dink-10,000	400143
L304	"	"	"	" "	"
L305	"	Var.	5.3 - 8.2 mH	CTC 3338-30	400212
L306	"	Fixed	15 mH 5%	Stanwyck 615000	400181
L307	"	"	24 mH		400208
L308	"	"	180 mH 20%	Stanwyck Dink-180,000	400140
L309	"	Var.	1.27 - 1.90 mH	CTC 3338-27	400185
L310	"	Fixed	3.9 mH 5%	Stanwyck 539000	400201
L311	"	Var.	625 - 950 µH	CTC 3338-25	400186
L312	"	Fixed	560 µH 5%	Stanwyck Dink-560	400183
L313	"	Var.	325 - 455 µH	CTC 3642-44	400187
L314	"	"	68 - 96 µH	CTC 3642-36	400188
L315	"	Fixed	1.0 µH 10%	Nytronics WEE-1.0	400120
L316	"	Var.	22.4 - 31.6 µH	CTC 3642-30	400189
L317	"	Fixed	1.5 µH 10%	Nytronics WEE-1.5	500198
L318	"	"	2.2 µH 10%	Nytronics WEE-2.2	400197
L319	"	Var.	3.2 - 7.2 µH		400222
L320	"	"	0.8 - 1.8 µH		400223
L321	"	"	0.25 - 0.34 µH		400224
L322	"	Fixed	10 mH 5%	Stanwyck Dink-10,000	400143
L323	"	"	4.7 µH 10%	Nytronics WEE-4.7	400113
L324	"	"	2.2 µH 10%	Stanwyck Dink-2.2	400178
L401	Inductor,	Fixed	2 H	Glasseal TF250/40	440010
L402	"	"	220 µH 5%	Nytronics WEE-220	400118
L403	"	"	7 H	Coral 1313001	440009
L404	"	"	2 H	Glasseal TF250/40	440010

SEMICONDUCTORS

Reference		Description		BEC Part No.
CR101	Diode	Selected		530035
CR102	"	"		"
CR301	Diode	Silicon	T.I. 1N914	530043
CR302	"	"	"	"
CR303	"	Zener	Mot. 1N5245	530076
CR304	"	"	Mot. 1N5256B	530079
CR305	"	Selected		530034
CR306	"	"		"
CR307	"	Silicon	T.I. 1N914	530058
CR401	Rectifier, Bridge	1 A 600 V	Varo VE-68	532011
CR402	" "	6 A 100 V	Varo VH-148	532012
CR403	Diode	Zener, 7.2 V 1%	Mot. 0.5M7.2ZS1	530094
CR404	"	Silicon	T.I. 1N914	530058
CR405	"	"	"	"
CR406	"	Zener, 51 V 2%	Mot. 1N5262	530086
CR407	"	Silicon	T.I. 1N2070	530088
CR408	"	"	"	"
CR409	"	"	T.I. 1N914	530058
CR410	"	"	"	"
CR411	"	"	T.I. 1N2070	530088
CR412	"	"	"	"
CR413	"	"	"	"
CR414	"	Zener, 39 V 2%	Mot. 1N5259	530085
CR415	"	Zener, 100 V 2%	Mot. 1N5271	530084
CR416	"	Zener, 11 V 5%	Mot. 1N5241B	530082
CR417	"	Silicon	T.I. 1N2070	530088
CR418	"	Zener, 51 V 2%	Mot. 1N5262	530086
CR419	"	Zener, 110 V 5%	Mot. 1N5272B	530083
CR420	"	Zener, 11 V 5%	Mot. 1N5241B	530082
CR421	"	Silicon	T.I. 1N2070	530088
CR501	Diode	Silicon	T.I. 1N914	530058
CR502	"	"	"	"
CR503	"	"	"	"

Reference		Description		BEC Part No.
Q101	Transistor	NPN Silicon	Mot. MJE-340	528040
Q301	Transistor	NPN Silicon	Mot. 2N5088	528047
Q302	"	FET	RCA 40673	528054
Q303	"	FET	T.I. TIS58	528038
Q401	Transistor	PNP	Mot. 2N5193	528041
Q402	"	PNP	Mot. 2N4918	528033
Q403	"	PNP	Mot. 2N5193	528041
Q404	"	FET, N Channel	T.I. 2N3819	528055
Q405	"	NPN	Mot. MJE340	528040
Q406	"	"	"	"
Q407	"	"	"	"
Q408	"	"	"	"
Q409	"	"	"	"
Q410	"	Darlington	Mot. MPS A66	528048
Q411	"	NPN	Mot. 2N3903	528024
Q412	"	NPN	Mot. MJE 340	528040
Q413	"	NPN	"	"
Q414	"	Darlington	Mot. MPS A66	528048
Q415	"	NPN	Mot. MJE 340	528040
Q501	Transistor	Silicon PNP	Mot. 2N5087	528042
Q502	"	Silicon NPN	Mot. MPS A10	528043
Q503	"	"	"	"
Q504	"	"	"	"
Q505	"	"	"	"
Q506	"	FET N Channel	Mot. 2N3819	528022
Q507	"	"	"	"
Q508	"	Silicon PNP	Mot. 2N5087	528042
Q509	"	"	"	"

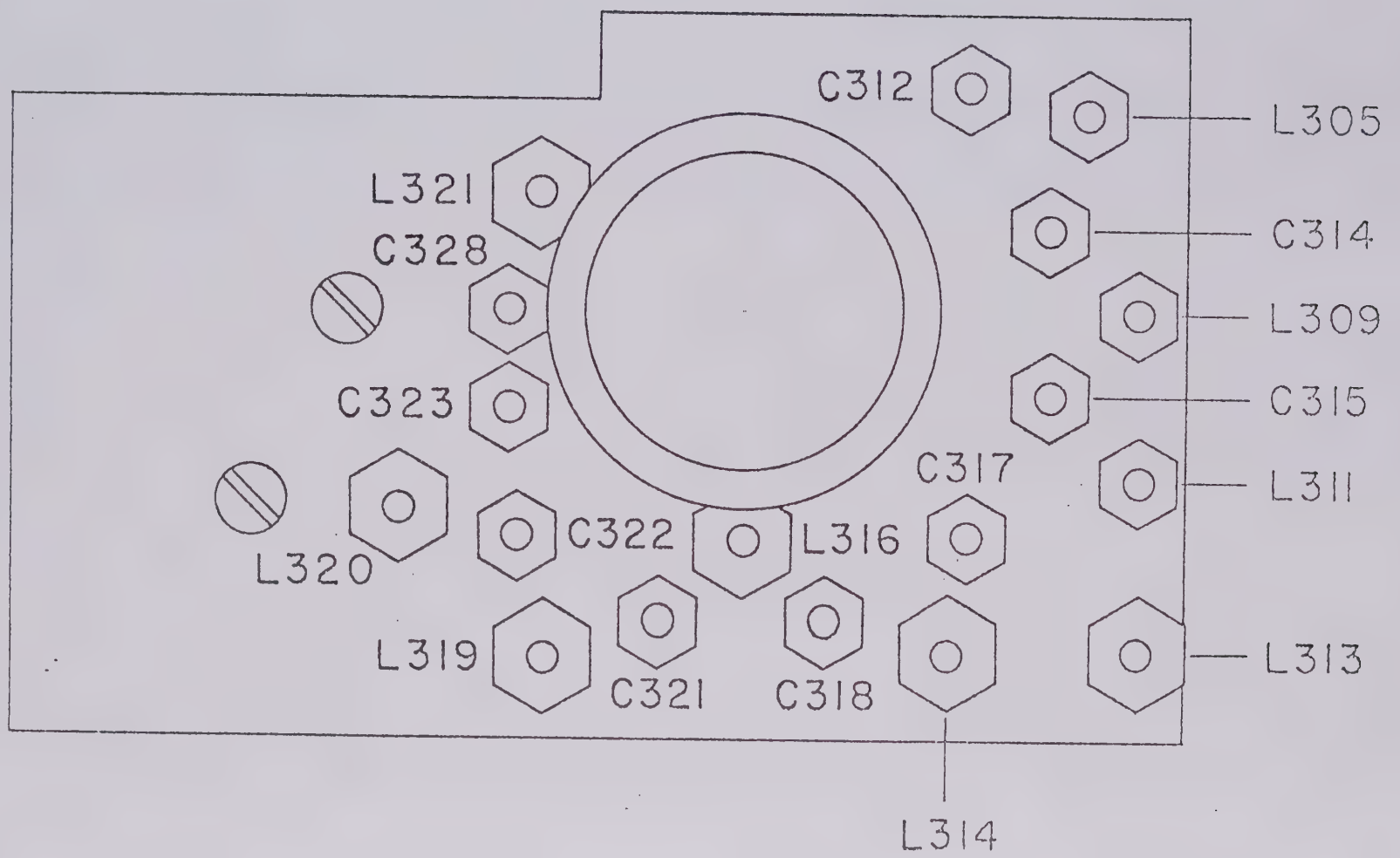
VACUUM TUBES

Reference		Reference		BEC Part No.
V101	Tube	6AK5/5654	G.E. only	525004
V102	"	7788	Amperex only	525007
V301	Tube	6DJ8	Amperex only	525006
V302	"	"	"	"
V303	"	7788	"	525007
V401	Tube	12AX7	Telefunken only	525001
V402	"	7199		5267199

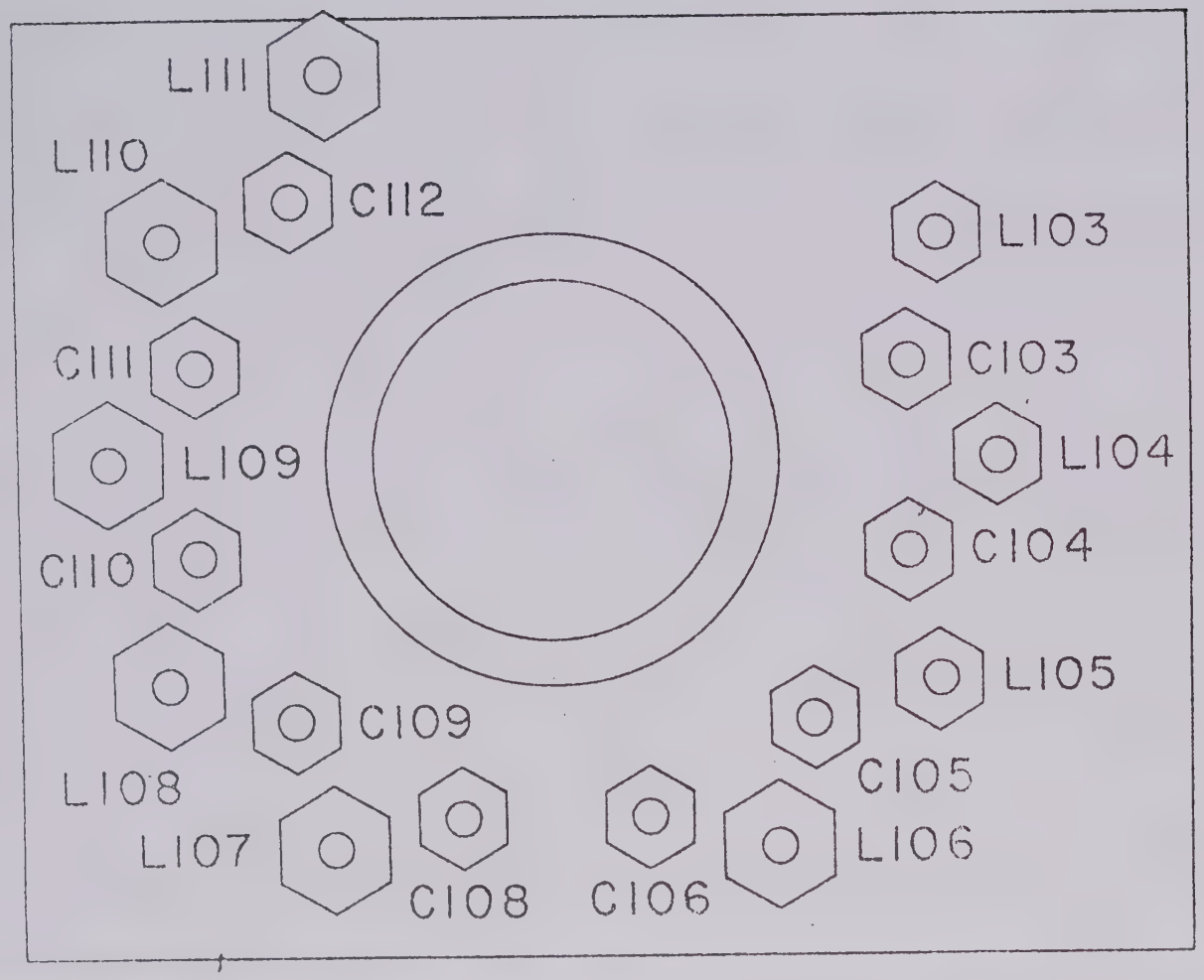
OTHER COMPONENTS

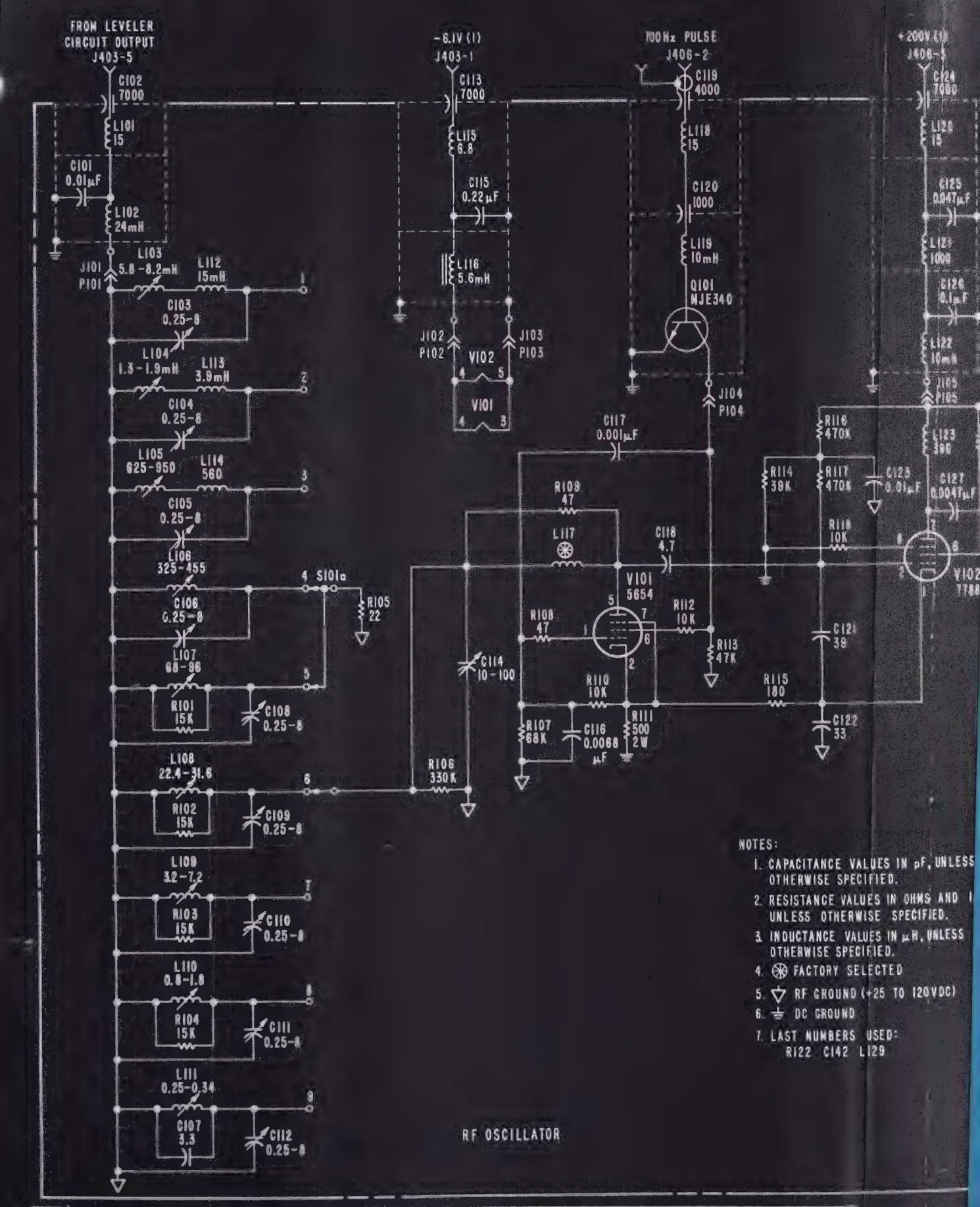
T401	Transformer	Power	Magnetic Windings	446050
T501	"	Miniature P.C.	Microtran DCM4-PC	445104
F401	Fuse	1 A 250 V (117 V)	Buss MDL-1	545510
F401	"	0.5 A 250 V (234 V)	Buss AGC 1/2	545502
F402	"	4 A 250 V	Buss AGC 4	545520
F403	"	0.25 A 250 V	Buss AGC 1/4 S/B	545506
J301	Connector	Right-Angle	Amp. 27-25	477252
J302	"	Receptacle	Bead Chain M-93-102	474253
to				
J307	"	"	"	"
J308	"	"	Amp. 60789-1	479232
J401	"	BNC	Dage 081-1	479123
J403	"	Pin	Molex 1561	479257
J406	"	Pin	Molex 1561	479257

Reference		Description		BEC Part No.
P301 to P307	Connector	Pin	Molex 1560	479253
P308	"	"	"	"
P401	"	Plug	Amp. 61097-1 Amp. 36775	477231 477171
S302		Band Switch	Ledex Series 312	466213
S401	Switch	Push-button, 2P 8 Pos.	CRL PB15	465136
S402	"	Slide, DPDT	Switchcraft 46256LF	465134
S403	"	Slide, SPST	" 46202L	465135
DS301 to DS309	Lamp	Aged & Selected	Chicago CM680	545119
	"	"	"	"


C312
L305
L321
C314
C328
L309
C323
C315
C317
L311
L320
C322
L316
L319
C321
C318
L313
L314

ZONE	REV.

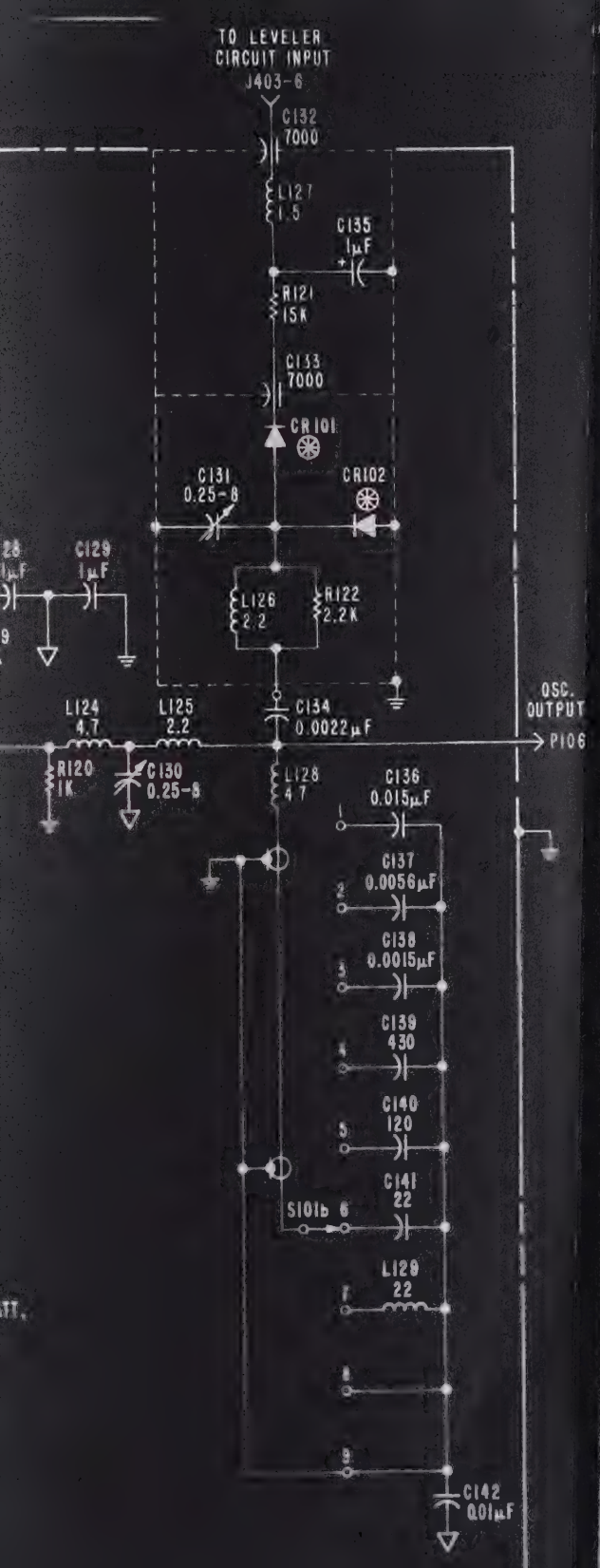

L111
L110
C112
C111
L109
C110
L108
C109
L107
C108
C106
L106
C105
L105
L104
C104
C103
L103



NOTES:

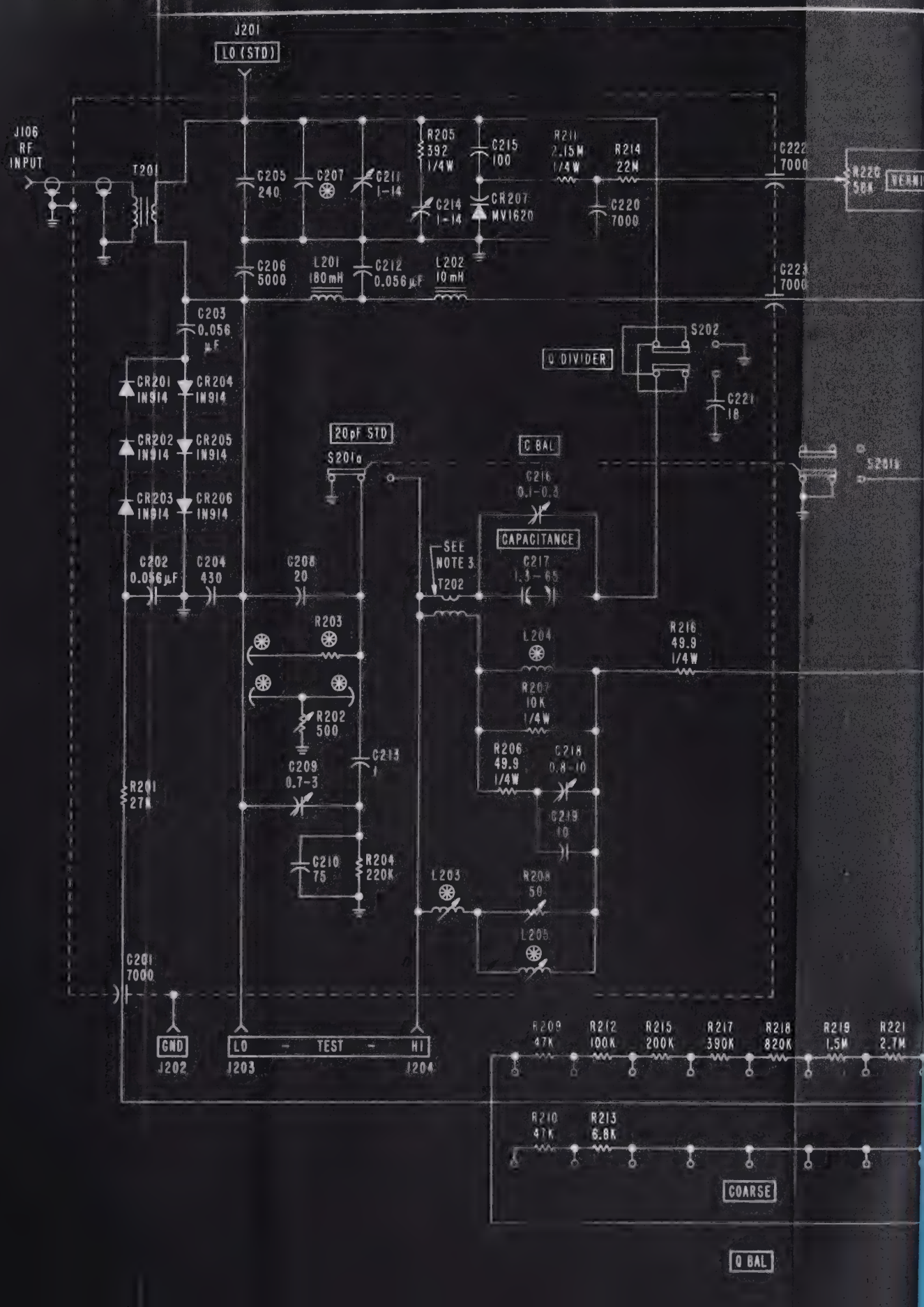
1. CAPACITANCE VALUES IN pF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS AND K UNLESS OTHERWISE SPECIFIED.
3. INDUCTANCE VALUES IN µH, UNLESS OTHERWISE SPECIFIED.
4. ⊛ FACTORY SELECTED
5. ▽ RF GROUND (+25 TO 120VDC)
6. ⏚ DC GROUND
7. LAST NUMBERS USED: R122 C142 L129

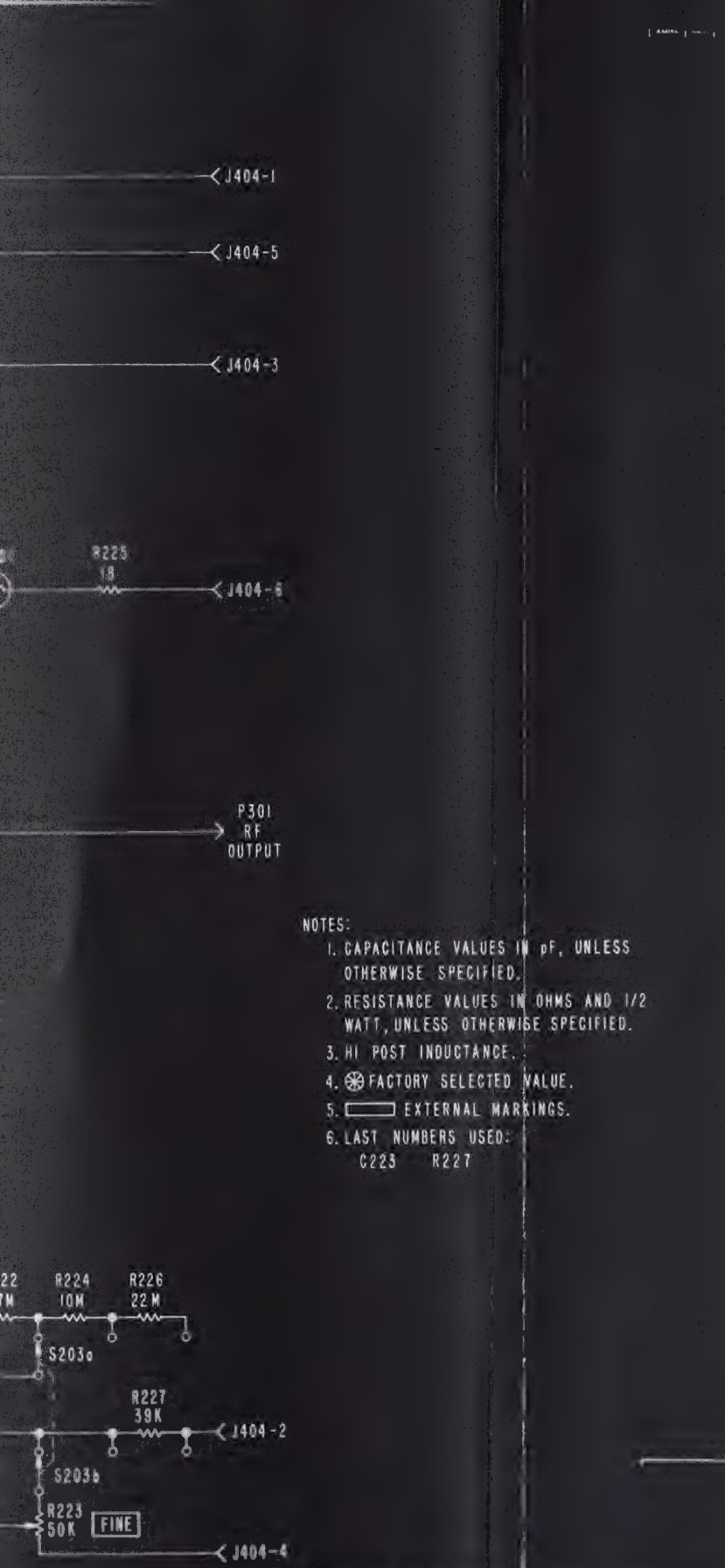
RF OSCILLATOR



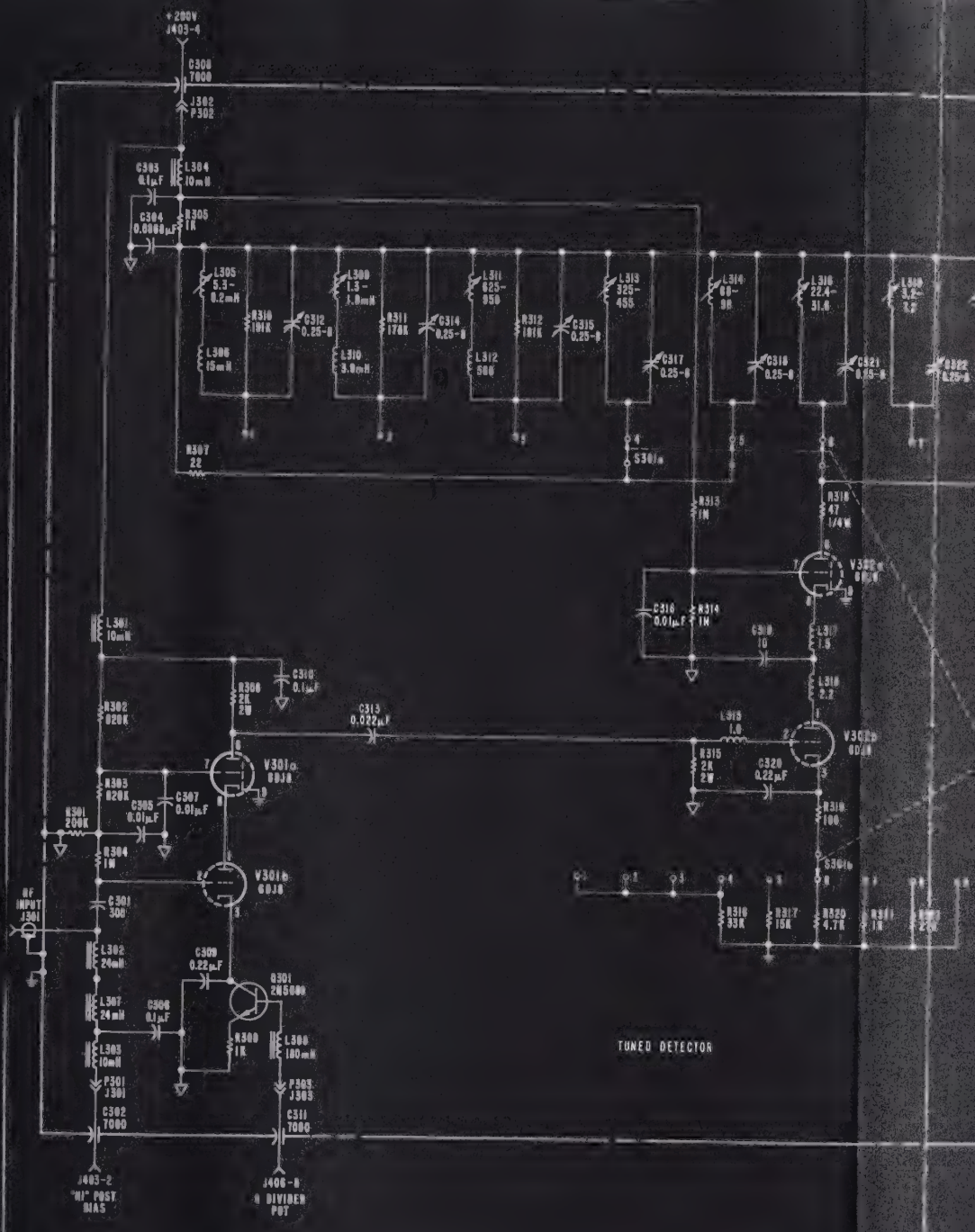
BOONTON ELECTRONICS CORPORATION

MODEL 35A
Schematic, RF Oscillator
D830488 D, Sh. 1 of 5


J201
LO (STD)
J106
RF
INPUT
T201
C205
240
C207
C211
1-14
R205
392
1/4W
C215
100
R211
2.15M
1/4W
R214
22M
C222
7000
C214
1-14
CR207
MV1620
C220
7000
C206
5000
L201
180mH
C212
0.056 µF
L202
10 mH
C223
7000
C203
0.056
µF
S202
Q DIVIDER
C221
18
CR201
IN914
CR204
IN914
CR202
IN914
CR205
IN914
CR203
IN914
CR206
IN914
20pF STD
S201a
C BAL
C216
0.1-0.3
CAPACITANCE
C217
1.3-65
SEE
NOTE 3
T202
C202
0.056µF
C204
430
C208
20
R203
R202
500
L204
R216
49.9
1/4W
R207
10K
1/4W
C213
1
C209
0.7-3
R206
49.9
1/4W
C218
0.8-10
C219
10
R201
27K
C210
75
R204
220K
L203
R208
50
L205
C201
7000
GND
J202
LO - TEST - HI
J203
J204
R209
47K
R212
100K
R215
200K
R217
390K
R218
820K
R219
1.5M
R221
2.7M
R210
47K
R213
6.8K
COARSE
Q BAL

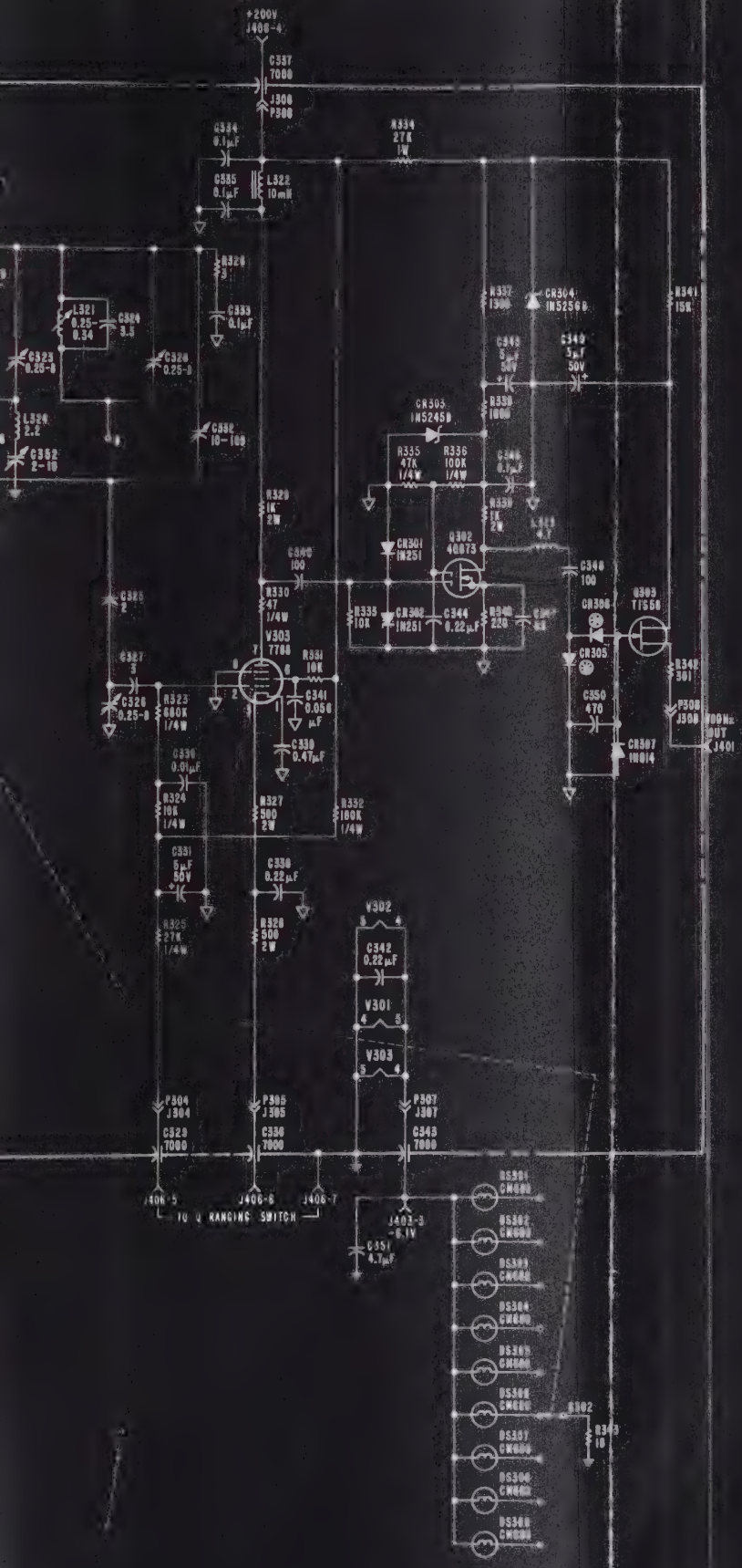


BOONTON ELECTRONICS CORPORATION
MODEL 35A
Schematic, Bridge
D830488A, Sh. 2 of 5



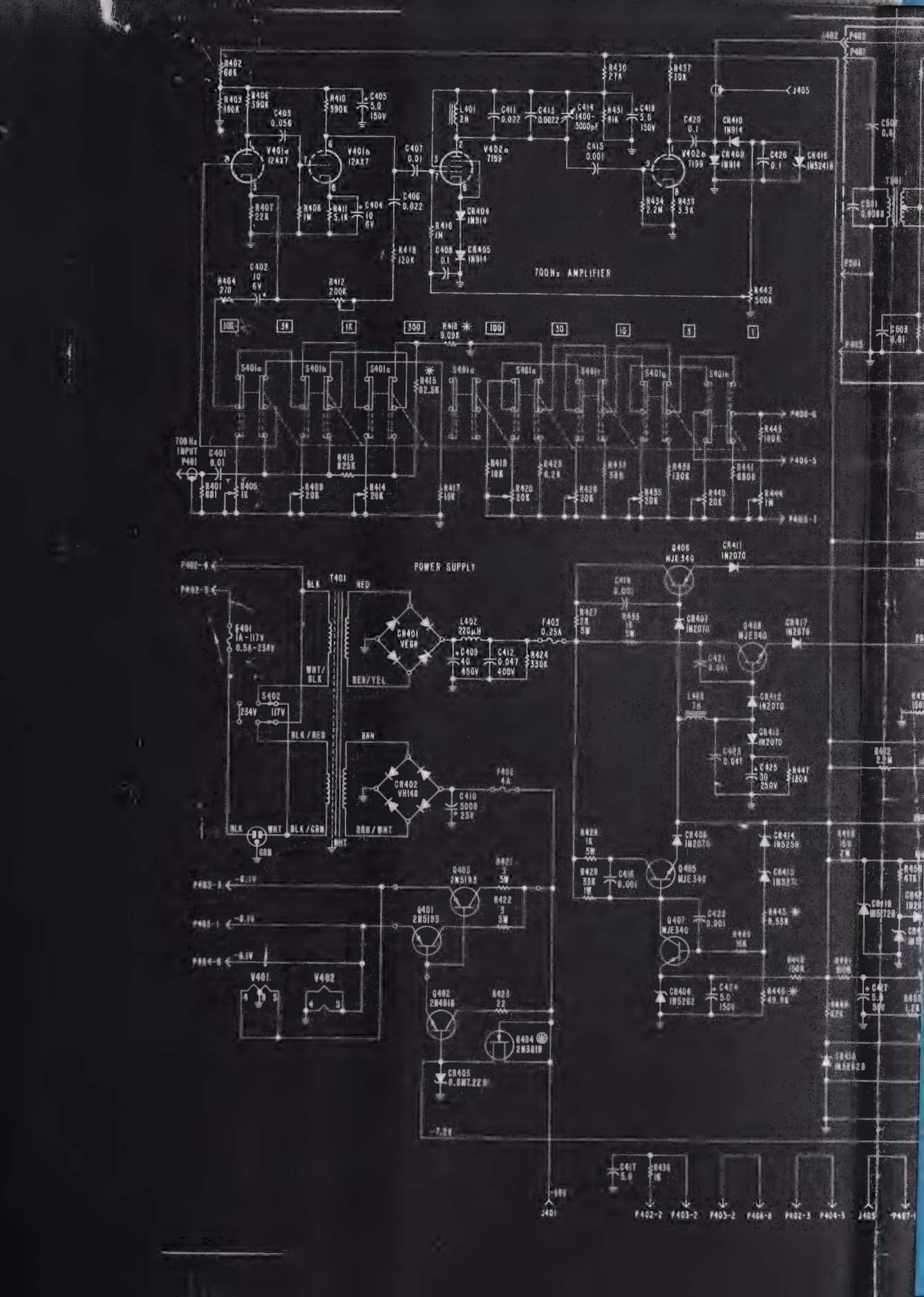
NOTES:

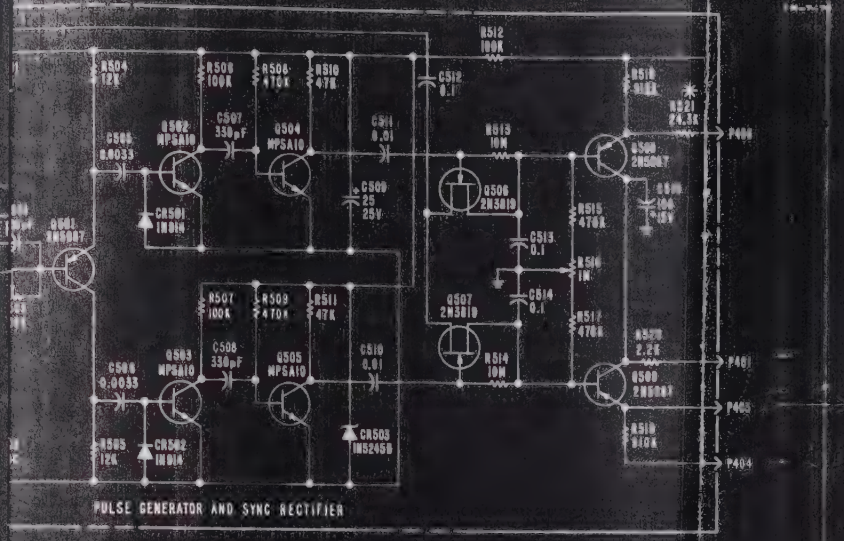
1. CAPACITANCE VALUES IN pF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS AND 1/2 WATT UNLESS OTHERWISE SPECIFIED.
3. INDUCTANCE VALUES IN μH, UNLESS OTHERWISE SPECIFIED.
4. ⊛ FACTORY SELECTED
5. ▽ RF GROUND
6. ⏚ DC GROUND
7. LAST NUMBERS USED R343 C352 L324

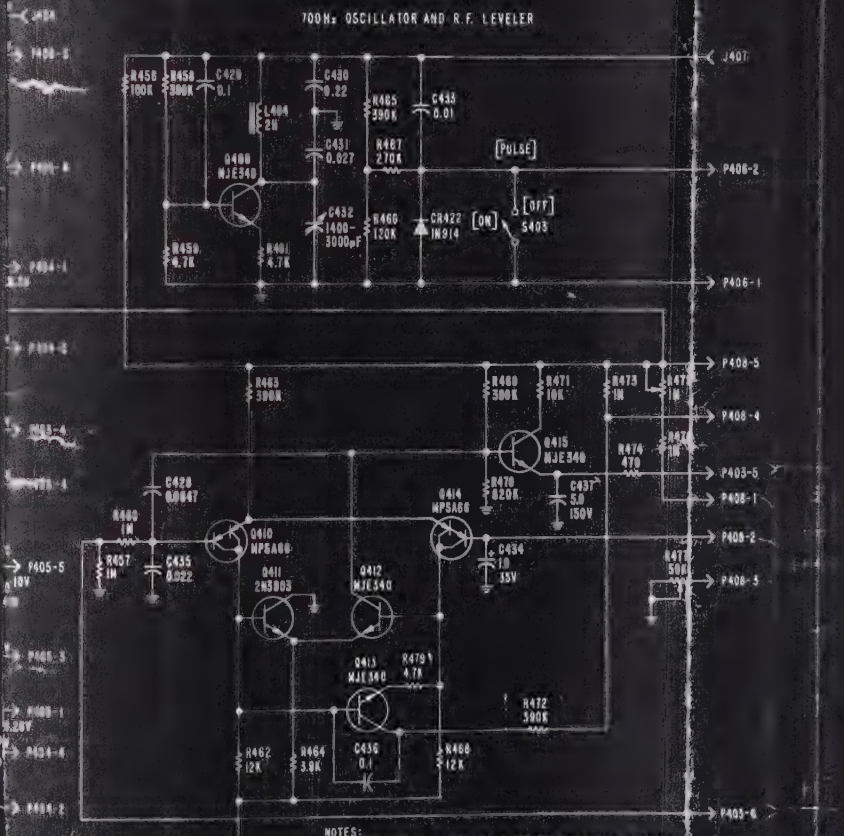


BOONTON ELECTRONICS CORPORATION

MODEL 35A
Schematic, Tuned Detector
E830488C, Sh. 3 of 5

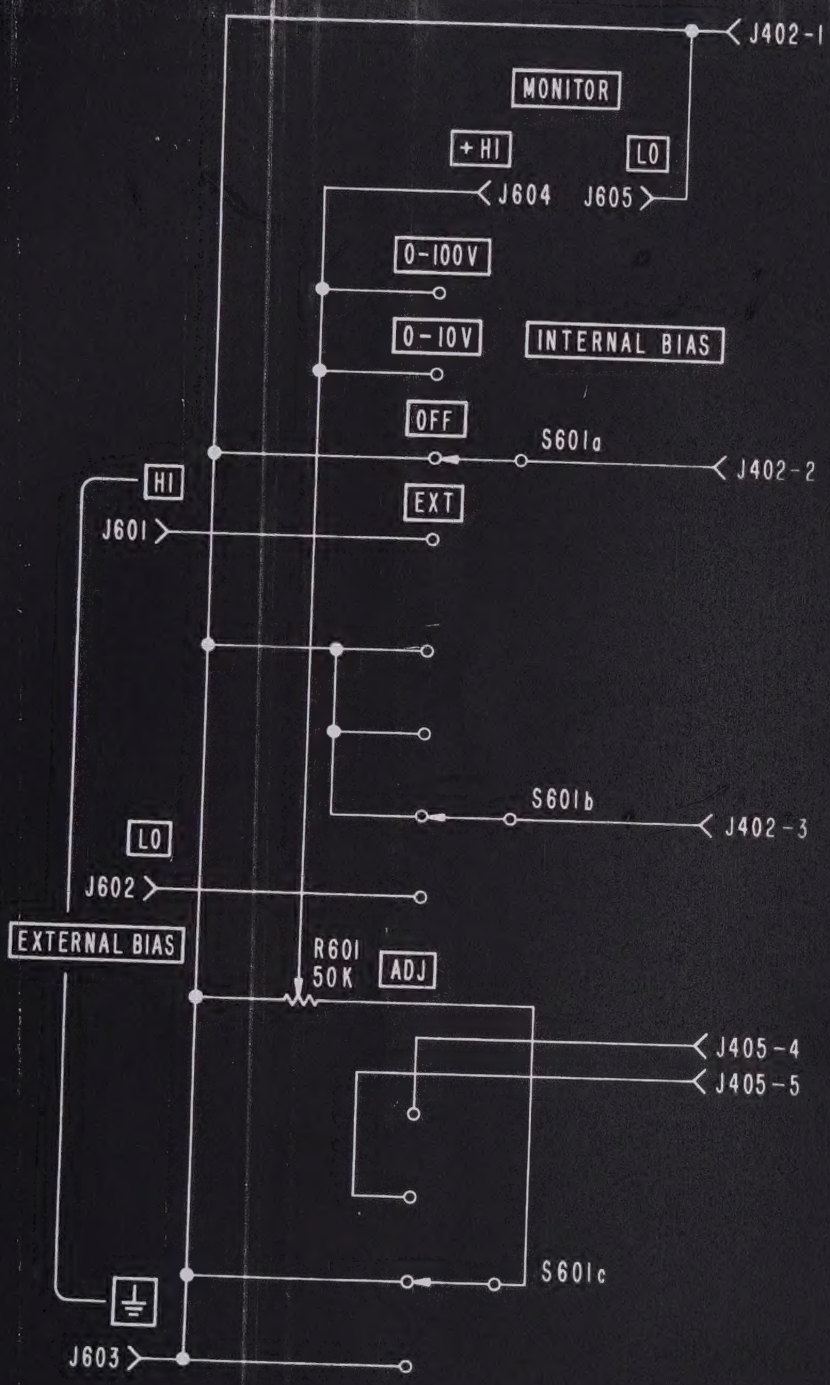

700Hz AMPLIFIER
POWER SUPPLY
700Hz INPUT
T401
S401a
S401b
S401c
S401d
S401e
S401f
S401g
S401h
S402
V401a 12AX7
V401b 12AX7
V402a 7199
V402b 7199
Q401 2N5193
Q402 2N4918
Q403 2N5193
Q404 2N3810
Q405 MJE340
Q406 MJE340
Q407 MJE340
Q408 MJE340
CR401 VE68
CR402 VH148
CR403 0.8W7.2V
CR404 IN914
CR405 IN914
CR406 IN5262
CR407 IN2070
CR408 IN2070
CR409 IN2070
CR410 IN914
CR411 IN2070
CR412 IN2070
CR413 IN2070
CR414 IN5258
CR415 IN5258
CR416 IN5258
CR417 IN2070
CR418 MG1720
CR419 IN5258
CR420 IN5258
L401 2H
L402 220µH
L403 7H
F401 1A-117V 0.5A-234V
F402 4A
F403 0.25A
S402 234V 117V
R402 68K
R403 180K
R404 270
R405 390K
R406 22K
R407 22K
R408 1M
R409 20K
R410 390K
R411 5.1K
R412 200K
R413 825K
R414 20K
R415 82.5K
R416 1M
R417 10K
R418 9.09K
R419 10K
R420 20K
R421 1K 5W
R422 3 5W
R423 22
R424 330K
R425 33K 1W
R426 1K 5W
R427 2K 5W
R428 20K
R429 33K 1W
R430 27K
R431 91K
R432 30K
R433 20K
R434 2.2W
R435 20K
R436 1K
R437 3.3K
R438 130K
R439 3.3K
R440 20K
R441 680R
R442 500K
R443 100K
R444 1M
R445 9.53K
R446 49.9K
R447 180K
C401 0.01
C402 10 6V
C403 0.056
C404 10 6V
C405 5.0 150V
C406 0.022
C407 0.01
C408 0.1
C409 40 450V
C410 5000 25V
C411 0.022
C412 0.047 400V
C413 0.0022
C414 1400-3000pF
C415 0.001
C416 0.001
C417 5.0
C418 5.0 150V
C420 0.1
C421 0.001
C422 0.001
C423 0.001
C424 5.0 150V
C425 30 250V
C426 0.1
C427 5.0 50V
C428 0.001
C429 0.001
C430 0.1
C501 0.0068
C503 0.01
J401
J402
J405
P401
P402-1
P402-2
P402-3
P402-4
P403-1
P403-2
P403-3
P404-1
P404-2
P404-3
P405
P406-1
P406-5
P406-6
P407-1
P407-2
P501
T501
BLK
RED
RED/YEL
WHT/BLK
BLK/RED
BRN
BRN/WHT
BLK/GRN
WHT
GRN
-8.2V
-8.1V
-8.6V
-14V
10K
3K
1K
300
100
30
10
3
1





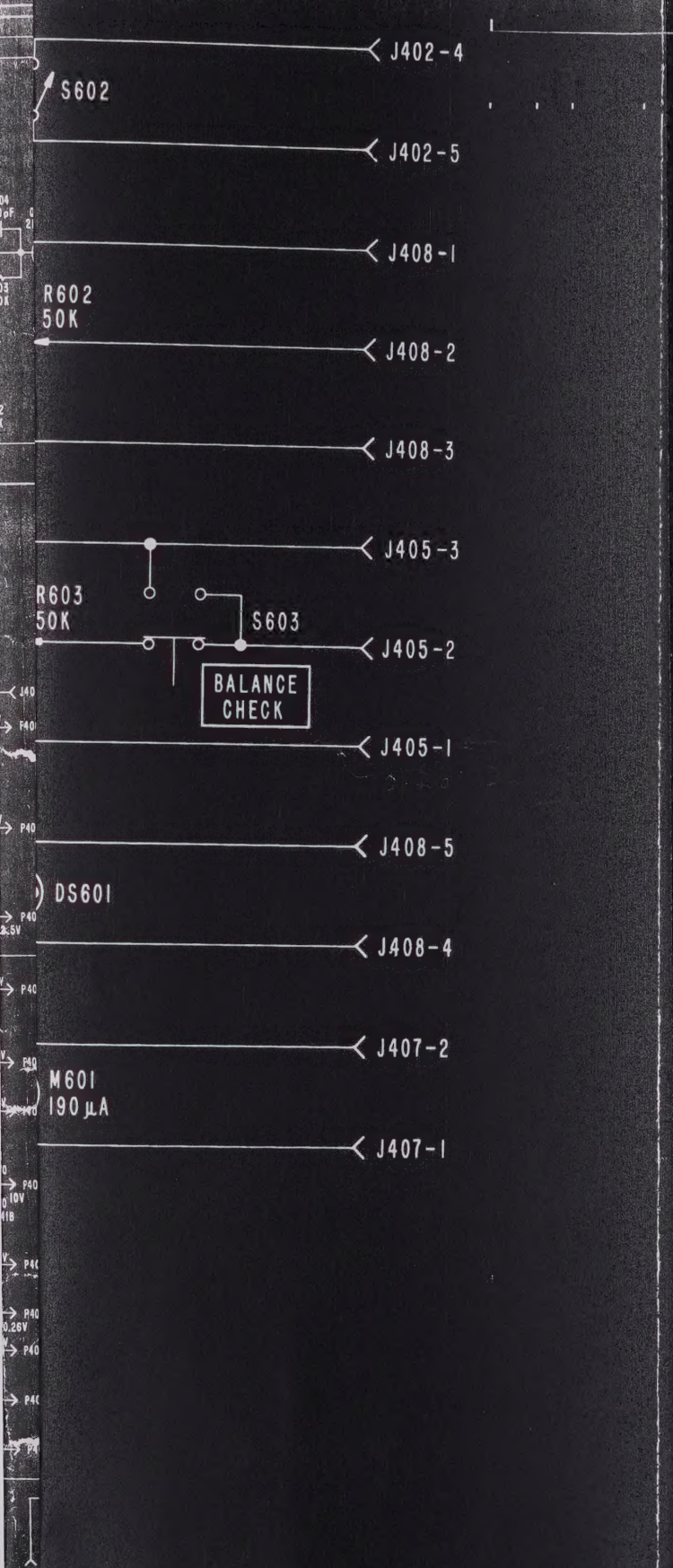
BOONTON ELECTRONICS CORPORATION

MODEL 35A
Schematic, Power Supply
E830488F, Sheet 4 of 5



NOTES:

1. RESISTANCE VALUES IN OHMS, UNLESS OTHERWISE SPECIFIED.
2. ▭ EXTERNAL MARKINGS.
3. LAST NUMBERS USED:
   R603



TEKTRONIX, INCORPORATED

MODEL 35A
Schematic, Front Panel
C830488A, Sh. 5 of 5

MP MASTER
MA24748